The Scenery of England

Lord Avebury

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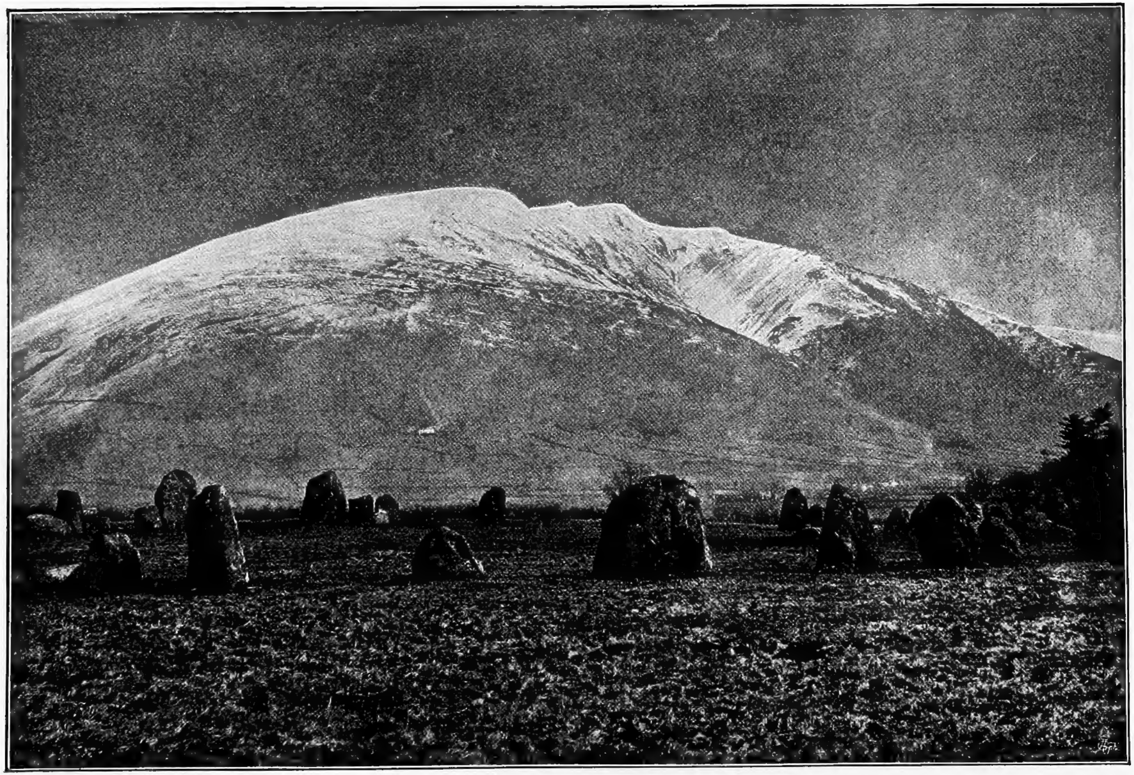

Saddleback, with Keswick Stone Circle in Foreground.

The Scenery of England and the Causes to which it is due

BY

THE RIGHT HON. LORD AVEBURY (Sir Jo

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Preface

THE favourable reception which has been accorded, both here and abroad, to my book on the *Scenery of Switzerland* has encouraged me to prepare a similar work on our own country. It may be said that we have already Sir A. Ramsay's excellent *Physical Geology of Great Britain.* Sir A. Ramsay's book, however, is mainly geological, of 600 pages, about 500 being devoted to geology. Moreover, he included Scotland, so that the space devoted strictly to the scenery of England and Wales was very limited.

Mackintosh's *Scenery of England and Wales* was written under the belief that the configuration, and consequently the scenery, was mainly due to marine action. Subsequent researches have led to, I think, a general agreement that subaerial action has been the "predominant partner"; and in various other directions Physical Geography has made great progress during the last thirty years.

Sir A. Geikie's charming *Scenery of Scotland*

viewed in connection with its Physical Geography deals, of course, only with the northern part of our island; and I do not venture into the domain which he has made his own.

For the geology proper the principal sources of reference are the admirable series of Memoirs and Maps issued by the Geological Survey, and the Proceedings of the Geological Society and the Geologists' Association. There are also many important separate works and innumerable memoirs in the publications of local Societies. The *Geographical Journal* contains many memoirs bearing on the subject; and altogether the literature is vast, and very much scattered.

No one can realise more vividly than I do the imperfection of my work. Nevertheless, if the book be half as interesting to read as I have found it to write, I may venture to hope that it may serve as an introduction to this fascinating branch of science.

I am very much indebted to Mr. Marr, who has been good enough to look through the proof-sheets, and to Mr. C. V. Crook, who has assisted me by seeing them through the press.

I am also indebted to Sir A. Geikie, Miss Dale, Professor Allen, Mr. Armstrong, Mr. Bingley, Mr. Cole, Mr. Defries, Professor Garwood, Mr. Strahan, Mr. A. S. Reid, Mr. Watson, Mr. Whitaker, Mr. Willis, Mr. H. B. Woodward, and to Mr. Abraham, Mrs.

Frith, Mr. Horner, and Mr. Wilson, for kindly permitting me to use various diagrams and illustrations, many of them beautiful specimens of photography.

Several of these are from the admirable series of "Photographs of Geological Interest in the United Kingdom," formed by a Committee of the British Association under the Chairmanship of Professor James Geikie, and of which Professor W. W. Watts is the energetic Secretary.

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Anticline, see p. 187.
Archæan, see p. 8.
Basalt. Volcanic rock. A compact form of Dolerite.
Boulder-clay, see p. 63.
Cambrian, see p. 12.
Carboniferous, see p. 16.
Cleavage, see p. 197.
Cretaceous, see p. 30.
Crystalline Schists, see p. 9.
Devonian, see p. 14.
Diabase. An igneous rock, regarded by some petrologists as an altered Basalt or Andesite.
Dip, see p. 187.
Diorite. An igneous rock. Plagioclastic Felspar, Hornblende, Magnetite, etc.
Dolerite. An igneous rock. Labradorite, Olivine, Magnetite, and Titaniferous Iron, with Augite.
Drift, see p. 63.
Eocene, see p. 32.
Erratics, see p. 70.
Escarpments, see pp. 91, 218.
Eskers, see p. 65.
Faults, see p. 203.
Foliation, see p. 196.
Gault, see p. 35.
Glaciers, see p. 49.
Gneiss, see p. 2.
Granite, see p. 4.
Greensand, see p. 31.
Greenstone. A term for igneous rock, including both Dolerites and Diorites.
Hastings Sand, see p. 34.
Inliers. Portions of an older bed surrounded by newer strata. They are usually due to some disturbance, or to irregular denudation.
Jurassic, see p. 25.
Lag faults, see p. 212.

Lias, see p. 25.
London Clay, see p. 39.
Millstone Grit, see p. 20.
Miocene, see p. 43.
Moraines, see p. 56.
Mountain Limestone, see p. 19.
New Red Sandstone, see p. 22.
Nummulites, see p. 196.
Old Red Sandstone, see p. 14.
Oligocene, see p. 42.
Oolites, see p. 27.
Outcrop. The edge of a rock which appears at the surface of the ground.
Outliers. Portions of any stratified group which lie detached from the main body, the intervening part having been removed by denudation.
Overthrust, see p. 209.
Oxford Clay, see p. 30.
Permian, see p. 22.
Pleistocene, see p. 70.
Pliocene, see p. 43.
Plutonic rocks. Igneous rocks which did not reach the surface.
Puys, see p. 230.
Quaternary, see p. 45.
Regimen of a river, see p. 287.
Screes, see p. 220.
Septaria. Nodules of argillaceous limestone or clay ironstone, divided by "septa," or cracks filled with mineral matter, usually calc-spar.
Serpentine, see p. 7.
Sill, see p. 239.
Silurian, see p. 13.
Slickensides, see p. 193.
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Trias, see p. 22.
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The Scenery of England

CHAPTER I

GEOLOGY

Vidi ego, quod fuerat quondam solidissima tellus,
Esse fretum: vidi factas ex aequore terras;
Et procul a pelago conchae jacuere marinae.
OVID, *Metam.* xv. 262.

Straits have I seen that cover now
What erst was solid earth; have trodden land
Where once was sea; and gathered inland far
Dry ocean shells.—*Ovid's Metam.*, trans. by H. KING.

THE scenery of any country so greatly depends on the structure and arrangement of the rocks of which it is composed, that it cannot be described without some reference to geological causes. Geology is, in fact, the geography of the past. I do not, however, propose to deal with that science further than is necessary for my present purpose.

The subject is one of great difficulty, and offers problems of the most vivid interest. The older rocks of our country probably date back to a time when no life existed on the earth; and of those which contain fossils, the earlier, and even some of the more recent,

have been subjected to such extremes of heat, pressure, and chemical action, that the fossils have often been entirely destroyed, and the very rocks themselves have been bent, folded, fractured, reversed, crushed, ground, and so completely metamorphosed that their whole character has been changed beyond recognition. As might naturally have been expected, the older rocks have on the whole undergone most change.

The continents are formed mainly of materials which once formed the bottom of seas and lakes, intermixed with igneous matter forced up from the fiery heart of the earth.

IGNEOUS ROCKS

Gneiss

To commence with the igneous rocks, Gneiss is composed of Quartz, Felspar, and Mica, with a more or less foliated structure.

The Felspar is generally white, but sometimes green or pink, and has often a waxy lustre; the Mica is white, brown, or black. The Quartz forms a sort of paste wrapping round the other ingredients.

Gneiss presents the same general characters all over the world. It is not all of the same age, and though some may be comparatively recent, at any rate the oldest rock we know is Gneiss. This gives it a peculiar interest. The foliation of the Gneiss is probably of two kinds: the one due to pressure,

crushing, and shearing of an original igneous rock such as Granite, the other to original segregation-structure.[1]

"Gneiss," says Professor Bonney, "may be, if not actually part of the primitive crust of the earth, masses extruded at a time when molten rock could be reached everywhere near to the surface."[2] When the crust of the earth first began to solidify, the waters of the present ocean must have floated in the atmosphere as steam, so that even at the surface there would be a pressure equal to more than 12,000 feet of water. The cooling also must have been very slow. Still the original crust, if we use the words in their popular sense to mean the superficial layers, was probably more like basalt, or the lavas of our existing volcanoes. Gneiss, on the other hand, must have cooled and solidified under tremendous pressure and at a great depth. When we stand on a bare surface of Gneiss or Granite we must remember—and it is interesting to do so—that it must have been originally covered by several thousand feet of rock, all of which have been removed.

"Probably," says Sir A. Geikie, "the great majority of geologists now adopt in some form the opinion that the oldest or so-called 'Archæan' Gneisses are essentially eruptive rocks. . . . Whether they were portions of an original molten 'magma' protruded from beneath the crust or were produced by a re-fusion of already solidified parts of that crust or of

[1] Heim, *Beitr. z. Geol. K. d. Schw.*, L. xxiv.; Geikie, *Text-book of Geology*.

[2] *Story of our Planet.*

ancient *sedimentary* accumulations laid down upon it, must be matter of speculation."[1]

On the other hand, Gneiss is certainly not all of the same age, since in some instances it traverses other strata. There appear, moreover, to be cases in which *sedimentary* strata have been metamorphosed by heat or pressure into a rock which cannot mineralogically be distinguished from Gneiss.

Gneiss occupies a large part of Scotland, but in England rarely appears at the surface, though here as elsewhere it probably forms the fundamental rock, and would, it is thought, be found everywhere if we could penetrate deep enough.

Granite

Granite, like Gneiss, is composed of Quartz, Mica, and Felspar, but differs from it in not being foliated.

It is a plutonic rock and may be of any age; it often sends veins into the surrounding strata, which are then forced out of position, in which case they show evidence as they approach the Granite of being much altered by heat. It solidified at a great depth below the surface, and its upper portions probably flowed out as lava. It presents many varieties: if the Felspar crystals are large and well defined, it is known in popular language as Porphyry. Syenite consists of Felspar, Hornblende, and sometimes a little Quartz.

[1] *Text-book of Geology.*

Granite, like Gneiss, must have solidified under immense pressure, and therefore at a great depth. In the first place, the crystals it contains could not have been formed unless the process of cooling had been very slow. In addition to this, they present a great number of minute cavities containing water, liquefied carbonic acid, and other volatile substances. The whiteness of Quartz is due to these minute cavities. Sorby, whose main conclusions have since been verified by others, has endeavoured to calculate what must have been the pressure under which Granite solidified, by measuring the amount of contraction in the liquids which have been there imprisoned. He considered that the Granites which he examined must have consolidated under pressure equivalent to that of from 30,000 to 80,000 feet of rock. This is the more striking if we remember that what are now the highest mountains in Europe and Asia consist in great part of Granite.

The slower the process of cooling, the more time is given for crystallisation. Hence the very same molten mass at a great depth might, on cooling, produce a Granite with large crystals, higher up much smaller ones, still nearer the surface lava, and at the surface itself volcanic ash.

It used to be supposed that Granite was necessarily a very ancient rock, but it is now known that it does not belong to any particular period. Fig. 1 represents an intrusion of Granite into dark slate near Festiniog.

Granite or Granitic rock occurs principally in the

Fig. 1.—Intrusion of Granite into Slate, Festiniog. The Granite is pale, the Slates are darker, and foliated.

Lake District, and in Devon and Cornwall, where it forms five principal and several minor bosses.

The Cheesewring Granite from near Liskeard was used in the construction of Waterloo and Westminster Bridges, the Thames Embankment, and the London Docks; Peterhead Granite for the pillars of Fishmongers' Hall and the Carlton Club.[1]

The Felspar in Granite gives rise to a white clay (Kaolin), which is largely worked in Devonshire and Cornwall, especially near St. Austell, to be employed in the manufacture of china. It is also used in bleaching-works and paper-mills.

SERPENTINE

Serpentine is a compact or finely granular rock, olive-green, brown, yellow, or red, and has a more or less silky lustre. There has been much doubt as to its origin, but it is now regarded generally as an altered igneous rock.

SEDIMENTARY STRATA

The following table gives the order of succession of the different formations:—

Post Tertiary.	Recent. Quaternary or Pleistocene.
Tertiary or Cainozoic.	Pliocene. Miocene. Oligocene. Eocene.

[1] Hull, *Building and Ornamental Stones.*

Secondary or Mesozoic.	Cretaceous. Jurassic. Triassic.
Primary or Palæozoic.	Permian. Carboniferous. Devonian and Old Red Sandstone. Silurian. Cambrian.
Archæan.	
Fundamental Gneiss.	

To prevent any misunderstanding, it may be well to mention that geologists apply the term "rock" to any stratum, irrespective of hardness. Thus they speak even of sand or clay technically as a "rock."

It must also be remembered that the names which have been given to the great geological series represent time rather than structure or composition. Just as gravel is at the present time being deposited in some places, sand or clay, calcareous mud or volcanic matter in others, so it has been in former times of the earth's history. Thus, while Chalk is the most typical representative of the Cretaceous system, the rocks of that period comprise also layers of sand, clay, gravel, etc. While the Chalk was being deposited in deep seas far from land, sands, gravels, and clay were being formed elsewhere.

Coal occurs not only in the Carboniferous strata, but in the Jurassic and Tertiaries, though not in large quantities or of so good a quality. Such names as the Greensand series, Oolitic series, Chalk, etc., indicate the condition of the strata

belonging to those respective periods at the places where they were first studied and determined; but it must be remembered that there are Greensands, Oolites, and rock resembling Chalk but belonging to other periods, and that while the typical Greensands were being deposited in certain parts of England other rocks of a very different character were being formed elsewhere. Still, in dealing with a limited portion of the earth's surface, such as England, we often find that the deposits of a given period present certain definite characteristics.

The sequence of the rocks is indicated partly by their relative position, and partly by the fossils they contain.

ARCHÆAN

Between the Gneiss and the unmistakably sedimentary rocks there often lie immense masses of Crystalline Schists, sometimes indeed several thousand feet in thickness. Their origin is often difficult, or even in some cases impossible, to determine, as no fossils have been found in them, though the presence of Graphite and seams of Limestone has been supposed to indicate the existence of vegetable and animal life. Traces resembling worm-casts have indeed been found, and a remarkable structure in the Laurentian rocks of Canada has been named "Eozoon" by Sir J. W. Dawson. The organic origin of the latter is, however, more than doubtful. Archæan rocks occur in the Hebrides, in parts of Wales, and in Devon and Cornwall. The Malvern Hills probably

belong to this period, as also the Wrekin, the Longmynd, and the older rocks of Charnwood Forest in Leicestershire. Dr. Callaway claims for the rocks forming the heart of the Wrekin the honour of being the oldest in England.

The more ancient were perhaps deposited while the waters of the ocean were still at a high temperature. So generally distributed are these Schists, that in the opinion of many geologists they everywhere underlie the other stratified formations as a general platform or foundation. In some places, as for instance in parts of Switzerland, sedimentary strata have been so much modified by pressure, and in many cases by heat, that it is difficult, and in places impossible, to distinguish them from the older Crystalline Schists. "At one end," says Sir A. Geikie, "stand rocks which are unmistakably of sedimentary origin, for their original bedding can often be distinctly seen. At the other end come coarsely crystalline masses, which in many respects resemble Granite, and the original character of which is not obvious." The Upper Schists present three extreme types—Calcareous Schist, Mica Schist, and Quartz Schist, which appear to represent ancient limestones, clays, and sandstones respectively. Some of these probably are metamorphosed Palæozoic rocks, but in the absence of fossils this cannot be determined. The lower Crystalline Schists are probably of igneous origin. They are generally intensely folded and crumpled. The presence of boulders of foliated Crystalline Schist in the Carboniferous Puddingstones proves that the foliation

was original, or at least anterior to the Coal period.[1]

The problems, however, presented by these rocks are so many and so difficult that comparatively little progress has yet been made in their solution.

The Archæan rocks are greatly metamorphosed and

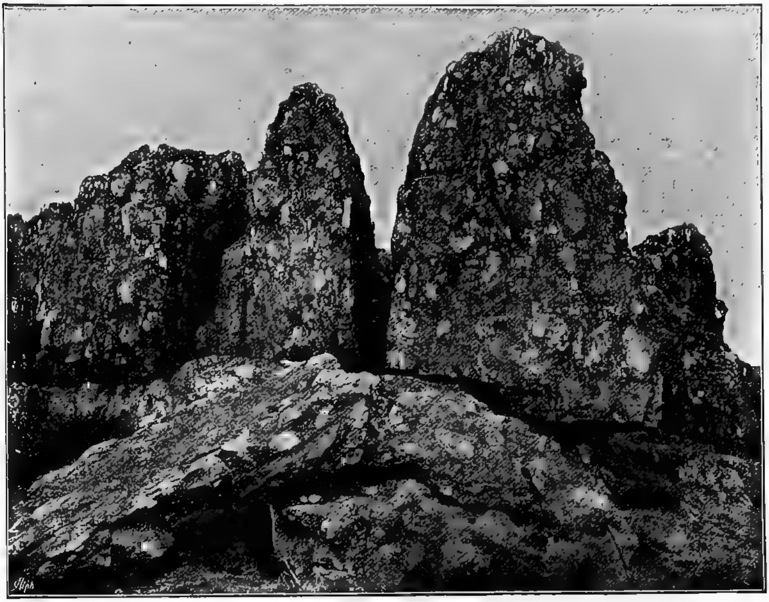


Fig. 2.—Pre-Cambrian Agglomerate, Charnwood Forest.

contorted. They consist of Gneissose, Schistose, Quartzose, and Granitoid rocks, Slates, Volcanic Agglomerates, and Breccias. Blue slates of this period have been used in the Albert Memorial, Hyde Park.

That the pre-Cambrian rocks were far older than the Cambrian is indicated by the fact that whenever

[1] Lory, "Comptes Rendus," *Cong. Geol. Int.*, 1888.

fragments occur in later rocks they are indurated, showing that they had already been metamorphosed before the subsequent rocks were deposited.

The photograph on the preceding page (Fig. 2) is of the pre-Cambrian Agglomerate in Charnwood Forest.

CAMBRIAN

The term Cambrian was proposed by Sedgwick because the rocks of this period are largely developed in Wales, the ancient Cambria. Unfortunately there has been much difference of opinion as to the boundary which should be drawn between the rocks of the Cambrian and those which should be included in the following or Silurian period. Many of the beds which Sedgwick regarded as Cambrian, Murchison considered to be Lower Silurian, and there is still some difference of opinion as to where the line of demarcation should be drawn.

If we use the term in its wider sense, the Cambrian strata are estimated to attain a thickness of at least 15,000 feet.[1] They consist of slates, grits, volcanic rocks, and subordinate beds of limestone. They were in the main deposited in shallow seas. Ripple-marks and even rain-pittings have been met with; but some of the strata indicate deep water. The period was one of considerable volcanic activity, some of our volcanoes having probably been as lofty as Mount Etna. The Lower Cambrian strata are the earliest in

[1] In the estimates of thickness I follow the useful table drawn up by Dr. Woodward and H. B. Woodward.

which we find well-preserved fossils. It is remarkable that many classes are represented — Sponges; Corals; Graptolites; Echinoderms (Star-fish and Crinoids); Worms; among Mollusca, Brachiopods, Lamellibranchs, Gasteropods, and in the higher strata even Cephalopods (Cuttle-fish); and Crustacea (Trilobites, Entomostraca). This fauna is clearly marine, but the sandy beds indicate the proximity of land.

Traces of seaweeds are met with, but no land plants belonging to this period have yet been determined.

Sir A. Ramsay has suggested that some of the red and purple beds may have been deposited in lakes or inland seas, and this is the more probable because sun-cracks and the pits made by rain-drops occur on the surface of some of the beds.

Cambrian rocks occupy a considerable area in Wales; they are well seen in the Passes of Llanberis and Nant Ffrancon, and supply the celebrated slates of Penrhyn and Llanberis. They also occur in Shropshire, the Malvern Hills, and in the Lake District.

The completeness with which so many great groups of Invertebrata are represented shows that the Cambrian strata represent a period far subsequent to the origin of life upon our planet. The absence of fossils in the earlier strata does not therefore indicate the non-existence of living beings, but the rocks have been so metamorphosed that the fossils have been destroyed. We cannot doubt that if, or when, we meet with stratified Archæan rocks in their primitive condition, they will be found to contain remains of animals and plants.

SILURIAN

The Silurian period was so named by Sir R. Murchison because it is well represented by rocks which occupy a part of the country inhabited by the Ancient British tribe known as the Silures. He tells us that "when Ostorius, the Roman general, conquered Caractacus, he boasted that he had blotted out the very name of the Silures from the face of the earth. A British geologist had, therefore, some pride in restoring to currency the word Silurian, as connected with great glory in the annals of his country."

The rocks of this period comprise slates, shales, and grits, with beds of limestone containing Corals and Encrinites. These beds are mainly of marine origin, deposited in a subsiding area, but not for the most part in water of any very great depth. If we refer the volcanic rocks of North Wales and the Lake District to the Upper Cambrian, there is in England no evidence of outbursts of igneous action during this period. The total thickness of the strata is about 27,000 feet. A great part of Western Wales is formed of slates belonging to this period. Some of the rocks are rich in fossils. The Crustacea are especially remarkable, and one of them, Pterygotus, even attained a length of six feet. Insects and fish make their appearance, and we have the earliest known representatives of land plants.

DEVONIAN AND OLD RED SANDSTONE

These rocks come between the Silurian and Carboniferous. The Devonian rocks are slates, grits, sandstone, and limestone, with interbedded eruptive rocks. Like the older rocks they are much contorted, fractured, and in some places even reversed. They occupy much of Cornwall, Devonshire, and part of West Somerset.

The Old Red Sandstone, as its name denotes, is in the main a red sandstone, with some marls, shales, conglomerates, and cornstones. It includes parts of Monmouth, Hereford, Brecon, Shropshire, Radnor, Carmarthen, and Pembroke. It reappears here and there along the Mendips and near Bristol. The Old Red Sandstone is generally considered to have been deposited in inland seas and lakes, as was originally suggested by Fleming, the Devonian rocks being regarded as the marine equivalents. They comprise a thickness of some 4000 feet. The Old Red Sandstone has received a special charm through the graphic descriptions of Hugh Miller. Some of the conglomerates have been supposed to indicate a period of cold. They contain scratched pebbles somewhat resembling those in the moraines of existing and recent glaciers. The beds are often ripple-marked and false-bedded, implying shallow water.

The grandest exhibitions of the Old Red Sandstone in England and Wales, says Murchison, "appear in the escarpments of the Black Mountain of Herefordshire, and in those of the loftiest mountains of

South Wales, the Fans of Brecon and Carmarthen; the one 2860, the other 2590, feet above the sea. In no other tract of the world which I have visited, is there seen such a mass of red rocks (estimated at a thickness of not less than 8000 to 10,000 feet) so clearly intercalated between the Silurian and the Carboniferous strata."[1] The Lia Fail, or Coronation Stone, on which our sovereigns are crowned, is a block of Old Red Sandstone. This rock has also been much used for flagstones.

The red colour is due to peroxide of iron, which is known to be very injurious to animal life. Hence probably the scarcity of fossils. This especially applies to ground animals, such as most of the Mollusca; for when the iron was thrown down, fish might swim freely in the comparatively pure water above, and their remains in fact are found, though not in any great abundance.

In Sandstone of this age near Marwood, remains of trees (Lepidodendron, Calamites, etc.), foreshadowing the forest vegetation of the Coal-measures, have been discovered, including the earliest known Fern, and traces of Conifers.

The Devonian rocks, on the other hand, are rich in marine remains. The Corals especially are in some places so numerous as to suggest a coral reef. A section of a Devonian coral long formed one of the most popular patterns for calico dresses.

Beds belonging to this period have been met with below the Chalk in deep borings at and near London.

[1] *Siluria.*

CARBONIFEROUS

The Carboniferous series was so named by Conybeare in 1822, because, though Coal occurs in rocks of all ages in the world's history, our main supplies are derived from the strata of this period. The actual beds of Coal, however, form a very small part, amounting in this country to about 150 feet out of a total of 14,000. The rest consists of sandstone, grit, conglomerate, shale, clay, culm, and enormous beds of limestone.

The period does not appear to have been one of any great volcanic activity—at least in England; but eruptive rocks occur among the lower beds. At Brent Tor, near Tavistock, the volcanic rocks are so well preserved that it is difficult when standing on the beds of ashes to realise that they are of such enormous antiquity. The celebrated Whinsill, which forms so striking a feature in Teesdale, and to which the two waterfalls of High Foss (generally misspelt Force) and Cauldron Snout are due, is an intrusive basalt, which has altered the beds both below and above it. The Coal-measures are intersected by almost innumerable faults and dykes. Northumberland and Durham are traversed from west to east by two great faults. Some of the faults do not represent any great change of level, but others are more important, such as the "Forty-fathom Dyke" and the great "Ninety-fathom Dyke." Few of the faults extend to the overlying strata, showing that the majority are of great antiquity.

Though the series has justly been named from the coal-beds, it contains many other useful minerals, especially rich deposits of iron-ore and building-stones (the Millstone Grit is so called from its forming excellent millstones), the Newcastle grindstones, Sheffield grindstones, fireclays, paving-stones, marble, and others of minor importance. The Carboniferous Limestone of North Wales, Derbyshire, Lancashire, and Yorkshire has also contributed large supplies of lead.

The Carboniferous strata contain numerous Corals, Worms, Molluscs, including a Cuttle-fish (Orthoceras), with a shell about 6 feet in length; Crustacea, including the last representatives of the Trilobites; Insects allied to the existing cockroaches and beetles; Myriapods; Spiders; Scorpions; Fish, one of which (Rhizodus) attained a length of 18 feet; while gigantic Amphibia (the group to which frogs, toads, and newts belong) and Reptiles also make their appearance. The most characteristic fossils, however, are the remains of a rich vegetation (indicating, according to Sir Joseph Hooker, a moist, equable, and temperate climate), and consisting mainly of Ferns, Horsetails, gigantic Club Mosses, some Fungi, and a few Conifers.

Some of the beds were marine, others estuarine,—deposited in lakes and great river deltas, such as those of the present Ganges and Mississippi.

"Rain-pittings on the shales are not infrequent, together with sun-cracks and foot-prints of Labyrinthodont Amphibia. The rain-pittings in this case tell of showers falling on surfaces of moist mud, exposed

by the temporary retirement of fresh water; and the sun-cracks indicate the drying and shrinkage of that mud; and these joined with the footprints of Amphibia tell of daily events which by happy accidents got perpetuated, first by baking in the sun's rays; next, when the area was again overflowed, new layers of mud settled on these impressions, and afterwards became consolidated into shale; and thus we have, in a measure, fossilised sunshine, showers, and footsteps of old Amphibians, imprinted, during their occasional visits to the moist land, on the margin of the water in which they chiefly lived."[1]

The Carboniferous rocks extend across England from Devonshire through Somersetshire and South Wales, by Derbyshire, Nottinghamshire, and Yorkshire to Northumberland. The Pennine range between Yorkshire and Lancashire is formed by a Carboniferous anticline.

LOWER CARBONIFEROUS

The Carboniferous Limestone is generally a tough bluish-grey, often crystalline, rock. It is sometimes spoken of as Mountain Limestone, and was termed by Sedgwick the "Scar Limestone," from the rough precipices or "scars" to which it gives rise, such as the precipices on the borders of the Lake District, those of Ingleborough, Penyghent, Malham, etc. The maximum thickness is estimated to reach 3500 feet.

[1] Ramsay, *Phys. Geog. of Great Britain*

It forms the main mass of the Mendip Hills and the grand Cliffs of Cheddar. The islets known as the Holmes, in the Bristol Channel, are due to anticlinal ridges of Carboniferous Limestone. The gorge of the Avon is excavated partly through it.

This beautiful rock, says Sedgwick, "is almost entirely made up of animal remains, especially shells and corals; and must once have stretched far and wide among shores and shoals. . . . No formation in our island shows features of more play and beauty. The fair islands of Killarney—the Clefts of Cheddar and St. Vincent's Rocks—the delicious valleys of the Wye and the High Peak—and (to come nearer the Lake Country) the sublime gorge of Gordale—the fine grey precipices at the foot of Ingleborough—the caverns of Chapel-le-Dale and Clapham—the rocks of Kirkby Lonsdale bridge—and the great white terrace of Whitbarrow—all belong to the features of this limestone."[1]

The Carboniferous Limestone undulates in gentle folds, the synclines generally forming ridges, and the anticlines furrows, as so often happens elsewhere.

UPPER CARBONIFEROUS

Above the Mountain Limestone lies the Millstone Grit, the maximum thickness of which is estimated at 5500 feet. It forms the Derbyshire "Peak," or Kinder Scout (Fig. 102, p. 269), which is really a triangular plateau about 2000 feet high.

[1] Sedgwick, in Wordsworth's "Scenery of the Lakes."

The Millstone Grit consists of coarse sandstones, grits, shales, and conglomerates, with occasional seams of limestone and coal. It forms the foundation on which our coal-beds rest, and generally crops out along the margins of the coal-fields.

The Brimham Rocks, near Pateley Bridge, and the Ilkley Crags consist of this rock.

The Culm measures, which occupy a large part of Devon, belong to this period, but contain no coal.

The true Coal-measures attain a thickness of 8000 feet, and elsewhere much more—in Germany, for instance, over 20,000. Our coal-fields lie in synclinal hollows, but, though now separated from one another, were originally connected. Some of the actual seams of coal extend over a wide area: the Arley seam of Lancashire is considered to be the same as the Silkstone coal of Yorkshire, and must have originally spread over an area of 10,000 square miles. Coal itself consists of vegetable matter, much of which has lost its original structure, though woody fibres can often be detected, and in some cases trunks of trees, roots, leaves, fruits, and even spores are beautifully preserved. In fact, the "Better Bed" of Bradford is almost entirely a mass of spores and spore-cases.

The actual seams of coal range in thickness from a mere film to the great "Ten-yard" seam of 30 feet in the Dudley district.

Underneath each bed of actual coal is usually a layer of underclay, containing plants formerly known as Stigmaria, but which have been shown by Binney

to be the roots of Sigillaria. This layer of clay represents perhaps the soil upon which the trees grew.

PERMIAN

The last rocks of the Palæozoic period are known as Permian, from their great development in the Russian province of Perm. Deposits of the period flank the Carboniferous rocks on both sides of the Pennine range, overlie the Coal-measures of the Welsh borders, and also occur in Devonshire. They form the coast-line near Tynemouth. These picturesque cliffs consist of magnesian limestone. In the West, on the contrary, the Permian beds are composed mainly of red and brown sandstones, with conglomerates and breccias. The Permian rocks attain a thickness of 3000 feet. They are very poor in fossils. The Houses of Parliament are partly built of magnesian limestone from Mansfield in Derbyshire, but unfortunately it was not all extracted from the best beds; and the terrace at Trafalgar Square is paved with flags from Mansfield.

SECONDARY STRATA

TRIAS

The Trias was so named by Bronn because, on the continent, it falls into three main divisions, which, however, cannot be exactly correlated with our rocks. The Trias in England consists of pebble beds, marl, and sandstone. It was formerly classed with the

Permian from the prevalence of red colour in both, and the two together were named by Conybeare "New Red Sandstone," to distinguish them from the much older rocks of similar character which underlie the Carboniferous series. At the close of the Palæozoic period, however, the rocks were much compressed, contorted, and denuded, after which the Secondary strata were deposited uncomformably on them. The break in the Fauna occurs between the Permian and the Trias. It is on this account that the former is now regarded as Palæozoic and the latter as Secondary.

The New Red Sandstone rocks stretch across England from the mouth of the Tees to that of the Exe, sending off a spur to the Mersey and Cheshire. A detached area occurs in the valley of the Eden, showing that the strata formerly extended far beyond their present western limit. The strata being comparatively soft, they form on the whole a low plain.

The red colour has given rise to the names of many towns and villages—Retford, Radstock, Radford, Redmarley, etc. Most of the beautiful red cliffs of South Devon belong to this period. It is also largely developed in Cheshire.

The colour is due to the materials being coated with a thin film of peroxide of iron. Similar deposits are now known to be in course of formation in some of the Swedish and Finland lakes, and it is probable that these beds were in the main deposited in inland, more or less brackish, lakes. Hence perhaps the poverty in fossils and the dwarfish size

of many of the shells. It is probable that some of these lakes or inland seas were gradually drying up, and may be compared with the present Caspian. Hence perhaps the salt deposits of Cheshire and Worcestershire. Sir A. Ramsay considered that some of the beds were ancient Boulder-clays, formed under glacial conditions. Though the actual Red Sandstone is poor in fossils, some of the associated beds have given a rich harvest. The Labyrinthodons, gigantic animals allied to our present frogs, are characteristic. Among the most remarkable are the Reptiles — comprising Crocodilia (Crocodiles), Lacertilia (Lizards), and Deinosauria. Some remains discovered by Boyd Dawkins in these beds were at first regarded as Mammalian, and considered to belong to the oldest Mammal (Microlestes) yet known. They are now, however, considered by some authorities to be Reptilian.

Our kitchen-salt is largely obtained from the rock-salt deposits of this age in Cheshire and Worcestershire. They have been worked for more than 1000 years, as the salt of Droitwich was one of the sources of revenue granted to Worcester Cathedral by Kenulph, King of the Mercians, in A.D. 816. The removal of the salt has been going on for ages, and in certain districts has led to subsidence of the overlying rocks, thus giving rise to some of the Cheshire meres.

Among other useful contents of the rocks of this age may be mentioned galena, cobalt-ore, valuable building-stones, brick-earth, gypsum, etc. Some of

the beds were used by the Romans in the construction of Hadrian's Wall; York Minster is partly built of stone from Jackdaw Crag; Beverley Minster, from Swansea; Exeter Cathedral, of sandstone from Exmouth; and Chester Cathedral, from sandstone of the neighbourhood. The "Bunter" Sands belonging to this period are also important, as forming an immense reservoir of the purest water.

JURASSIC

The Jurassic strata were so named by Brongniart in 1829 from the Jura Mountains, where they are largely developed. They have been divided into two main groups—the Lias and Oolites. They attain a thickness of 3000 feet.

Lias

The name Lias is a quarrymen's term. It is supposed to be a corruption of "layers," and was first used by Mitchell as a scientific term in 1788.

The Lias has in England a thickness of about 1500 feet; it forms a belt stretching across the country from Lyme Regis to Whitby in Yorkshire. The harder strata form escarpments overlooking broad valleys excavated in the softer beds. The "Marlstone," one of those harder beds, forms a prominent ridge at Edgehill, overlooking broad meadow-land of Lower Lias Clay, which forms the

great hunting country of Melton Mowbray, the Vale of Belvoir, and Market Harborough.

The fossils are numerous and varied. The flying Reptiles (Pterodactyles) and great marine Saurians, the Ichthyosaurus or Fish-lizard, and the long-necked Plesiosaurus make their appearance. They were all three discovered by Miss Mary Anning. The Ichthyosaurus attained a length of 24 feet, and the Plesiosaurus not much less. Ammonites and Belemnites[1] are very characteristic Jurassic fossils. They belonged to the same great group as the modern Cuttle-fish. Ammonites were said in a local legend to have been serpents turned to stone by St. Keyna. Some of the beds contain numerous Insects, including grasshoppers, dragon-flies, beetles, etc. On the other hand some of the older groups—Trilobites, for instance—have died out.

In our country the Lias comprises thick beds of marl, clay, and sand, with shale and argillaceous limestone. The beds were probably laid down in warm seas containing islands and coral reefs.

Some of the layers form excellent paving- and building-stones, others are burnt for lime, and the clays are largely used for brick- and tile-making. The Cleveland iron-ore belongs to the Middle Lias, and there are also deposits of Fuller's-earth belonging to this period.

The rich pasture-lands on the clays give the celebrated "Double Gloucester," Stilton, and Cheddar

[1] Pounded Belemnites are said to be regarded in parts of central England as an excellent cure for rheumatism !

cheeses. The Middle Lias is largely devoted to fruit-growing, and is said to be particularly suitable for apples.

The county of Rutland (red land) is said to have been so named from the red beds of this period.

The Lias dips to the south-east below the more recent strata; it no doubt extended far to the north and west of its present boundaries. This is proved not only by general considerations, but by the existence of "outliers" or patches of strata which have escaped destruction, especially one in the North near Carlisle, one between Adderley and Wem in Shropshire, and one near Cardiff. Quite recently Sir A. Geikie has found blocks of Lias among the masses thrown out by a Tertiary volcano in the island of Arran, showing that the Lias once extended there also.

Oolites

The Oolitic strata were so named by William Smith from the peculiar structure which gives many of its beds a more or less, and often very, close resemblance to the roe of a fish. The little balls vary from the size of a pin's-head to that of a pea, and appear to be due to the deposit of carbonate of lime round minute particles of shell or coral. In many cases this appears to have occurred while the particles were kept in a to-and-fro movement by a gentle ripple of the water; in others, and perhaps generally, the Oolitic structure has

been developed in the rock subsequently to its deposition.

The rocks belonging to this period stretch across England to the south-east of the Lias from Dorsetshire to Yorkshire, forming bold escarpments—the Cotteswolds in Gloucestershire, the "Cliff" in Lincolnshire, and the Howard Hills in Yorkshire, as a rule sloping gently to the south-east. They form grand cliffs between Durlston Head and St. Aldhelm's, and their hardness as compared with the strata inland has given rise to the beautiful bays known as Lulworth Cove (Figs. 28 and 29, pp. 122, 124), and Durdle Door (Fig. 83, p. 211).

The Oolitic structure, though characteristic of this series, is exceptional. The rocks are generally sand, clay, and limestone. They were deposited in comparatively shallow seas: the Coral Rag is due to coral reefs, and indicates a warm climate, though Ramsay believed that glacial conditions prevailed during a portion of the period. It is possible that the mountains of Wales, the North of England, and Scotland formed islands in the Oolitic seas. Other beds are of estuarine origin, and the ripple-marks and worm-tracks which occur in some places suggest shallow shores, and some of the upper beds (Purbeck) are of fresh-water origin. The total thickness amounts to about 3000 feet.

Many of the beds are very rich in fossils. Among the more remarkable, in addition to numerous Molluscs, especially Ammonites and Belemnites, Corals, Echinoderms, Crustacea including species allied to

the lobster, and Insects, are many great Reptiles: as, for instance, Crocodiles (Teleosaurus), a great carnivorous reptile, the Megalosaurus, which attained a length of 30 feet, the gigantic Ceteosaurus, or Whale Lizard, probably 50 feet in length and perhaps amphibious; and, lastly, many species of Mammalia.

In some cases the remains are so well preserved that some reptilian eggs have been found near Cirencester, and the soft parts of Cuttle-fish, including even the inkbag. The Cuttle-fish seem to have formed a great part of the food of the Ichthyosauri, and their stomachs are often found stained by the ink. In fact, Moore tells us that he could trace it in nearly every specimen. Many of these great reptiles were marine, but some lived in estuaries or swamps, just as De la Beche tells us that he has often seen the caimans of Jamaica wallowing in the mud of the large shallow lagoons, their bodies half buried in it, and the tips of their snouts just projecting from the surface of the water.

The Purbeck Beds are rich in remains of trees, sometimes still standing on the ground from which they grew. The stools of these trees are locally known as Birds'-nests. They were principally Conifers and Cycads (Araucaria, Zamia, etc.).

Among the more important strata of this period may be mentioned the Midford Sands, which supply some of the best building-stone of the West of England: the Fuller's-earth, some 400 feet thick: the Bath Stone (Great Oolite): the Cornbrash, which

is one of the most persistent of the calcareous strata, extending almost uninterruptedly from Dorsetshire to Yorkshire, though rarely reaching a thickness of more than 40 feet: the Oxford Clay, which attains a thickness of 600 feet: the Coral Rag, made up of coral reefs and the debris of coral reefs, and of which (Headington stone) many of the Oxford colleges are built; it attains a thickness of 200 feet: the Kimmeridge Clay, a dark bluish-grey clay, containing beds of bituminous shale which have been used as fuel; it attains a thickness of 1200 feet: the Portland Beds, so named from the Isle of Portland, consisting of white, shelly, and Oolitic limestone, with nodules and layers of chert; it has been much quarried for building-stone; Westminster Abbey and London Bridge, Salisbury Cathedral, Rochester Cathedral, Wilton Abbey, and Wardour Castle were mainly built of it. Bath Oolite was used in the interior of St. Paul's Cathedral.

At the summit of the Oolitic series come the Purbeck Beds; they are so named from the Isle of Purbeck, where they are extensively worked; they are mainly, though not entirely, of fresh-water origin, and are sometimes regarded as more properly belonging to the base of the Cretaceous series: while other geologists regard the Weald series as belonging to the Oolites.

CRETACEOUS

The term Cretaceous was suggested by Fitton because the Chalk is the most important member

of the series. The Cretaceous strata attain a thickness of 3000 feet, and the main divisions are—

Upper Cretaceous.	Chalk.	
	Upper Greensand.	
	Gault.	
Lower Cretaceous.	Lower Greensand.	
	Weald Series	Weald Clay.
		Hastings Beds.

The fossil plants comprise Seaweeds, Ferns, Conifers, and Cycads. Among animals, Foraminifera and Sponges are abundant. Corals are comparatively rare. Molluscs and Fish are numerous; Annelids and Crustacea also occur. The Iguanodon, a great herbivorous reptile, was discovered by Mantell. One of the great Pterodactyles had an expanse of wing of 18 feet. Birds also make their appearance.

The Lower Cretaceous rocks consist of limestones, sands, sandstones, and clays, indicating shallow seas not far from land, and in some cases estuarine or fresh-water conditions, especially at the commencement of the period. Gradually, however, a considerable subsidence took place, and the Chalk was deposited in a deep sea, probably of from 500 to 2000 fathoms. It consists almost entirely of animal remains,—Molluscs, Foraminifera, Sponges, Echini, Star-fishes, etc., and the absence of pebbles or sand indicates that the shores of the Chalk sea were far distant. The existence of Chalk in Antrim, at Morven, and in the island of Mull in Scotland; of Chalk flints in the

drift of Lancashire and Wales,[1] strongly supports the views of Judd and other geologists that the Chalk once extended over most if not the whole of Wales, the North of England, and part of Scotland; that it in fact extended to the Atlantic, and that the Atlantic itself formed a part of the Chalk ocean, which has remained under water ever since. The Cretaceous strata extend across England from the east of Devonshire through Dorsetshire and Wiltshire, north-eastwards to Norfolk, and then sweep round northwards to Flamborough Head and Filey.

The Greensand was so named from the colour of some of its beds, which is due to green grains, shown by Ehrenberg and Carpenter to be in many cases internal casts of the chambers of microscopic shells (Foraminifera). The green colour is due to the presence of glauconite.

The south-eastern part of this area has, however, been thrown into a great boss or anticlinal arch (Fig. 106, p. 278) elevated along a line proceeding from Petersfield by Horsham and Ashdown Forest to Rye, and the centre of which has been planed away, probably by the sea, thus bringing the lower Cretaceous deposits again to the surface, and forming the Weald, which, as we shall see, has been carved into deep valleys by aerial action; and two depressions or "synclinal" valleys, that on the north constituting the lower Thames valley or London basin, that on the south the

[1] Fragments of Chalk have recently been found among the rocks ejected by a volcano in Arran, as already mentioned (p. 27), showing that it extended there.

Hampshire basin, and both occupied by the more recent Tertiary strata. The commencement of a second dome occupies the southern half of the Isle of Wight. The arch rises so abruptly that at Scratchells Bay near the Needles the Chalk, as is clearly shown by the lines of flint, is absolutely vertical (Fig. 22, p. 98).

Chalk is extensively burned for lime, especially along the Medway, and some of the layers form fair building-stone, as also do some of the Hastings Sand-beds, of which many of the Kentish churches and castles are built; the "Iguanodon" quarry near Maidstone is one of the largest in Kent; the quarries at Reigate "were formerly considered of such consequence that they were kept in the possession of the Crown, and a patent of Edward III. exists, authorising them to be worked for Windsor Castle. Henry VII.'s Chapel at Westminster was also built from them, as also the Church at Reigate." Flint is also much used for building. The Greensand contains deposits of Fuller's-earth, especially near Nutfield. Some of the white sands have been used for glass-making; near Godstone and Dorking the beds are largely worked for firestone; the scythe-stones and whetstones known as "Devonshire bats" come from the Upper Greensand. The Penpits near Stourhead, once regarded as the remains of a British village, are the remains of pits sunk for this stone. The septaria or concretions of carbonate of lime from the Lower Greensand are used in the manufacture of cement, and the clays for bricks; lastly, the Hastings

Beds were much worked for iron-ore, until the combination of coal and iron in the north rendered them unprofitable. The cannon of the fleet which defeated the Spanish Armada, and the old railings round St. Paul's Churchyard, were made of Wealden iron.

The Hastings Sands are well shown in the cliffs at Hastings: they form the high ground of Ashdown Forest and the rocks of Tunbridge Wells. Hastings and St. Leonards both stand on them: the old town, however, on the lower beds, which are known as Ashdown Sands; St. Leonards on the overlying Tunbridge Wells Sands. These two beds are normally separated by a bed of clay, but are here brought together by a fault. The sands in many places show "false bedding," due to the existence of sandbanks and various currents in the great rivers, to which they owe their origin.

The Weald Clay forms the low tract of country stretching from Romney Marsh by Ashford and Tunbridge to Reigate, Haslemere, Petworth, and Pevensey Level. It forms stiff wet land, was in former times mainly forest, and is still for the most part wood or pasture.

The Lower Greensand is sometimes loose, sometimes indurated into hard bands or masses of siliceous sandstone, as for instance in the hill on which was the Ancient British camp at Oldborough near Ightham. The Lower Greensand can be traced at intervals from the Isle of Wight, through Dorset to Devizes and Swindon, through Oxfordshire, where it forms the "sponge" gravel of Little Coxwell and the iron-

sands of Shotover, by Woburn to Caxton east of Cambridge. It gives rise to the Isle of Ely, appears in Norfolk at Sandringham, where it forms a picturesque escarpment reaching to Heacham and Hunstanton, and passes through Lincolnshire. The Speeton Clay north of Flamborough Head is also considered to belong to this period. The Lower Greensand forms the cliffs between Hythe and Folkestone; the picturesque high grounds of Haslemere, Hindhead, and Leith Hill; and an escarpment which sweeps round the Weald from Folkestone to Leith Hill, by Guildford and Godalming to the sea, just east of Eastbourne. The celebrated Kentish Rag, so largely quarried near Maidstone, occurs in the "Hythe Beds" belonging to this period.

The Gault is generally a stiff blue or bluish-grey clay, sometimes becoming calcareous or sandy and containing septaria. It forms low and often marshy ground, generally in pasture, forming a hollow between the Lower Greensand and the Chalk, but sometimes rises into hills, as for instance Black Ven near Lyme Regis. Gault is a local word signifying clay.

The Upper Greensand occupies a considerable area in the east of Devonshire, and no doubt once extended much farther westwards, as is shown by two "outliers" forming the hills of Great and Little Haldon, west of the estuary of the Exe. In Dorsetshire it forms a fertile strip of ground at the foot of the Downs. It crowns the hills of Pillesdon Pen and Lewesdon, gives its name to "Golden Cap," and caps Black Ven.

In the Weald the Upper Greensand sweeps round the great oval between the Gault and the Chalk, but forms a narrow band, and indeed is in Kent but seldom exposed at the surface.

The layers of Chalk have a maximum thickness in England of 1750 feet, and it is even thicker elsewhere; so that when we consider the mode of its formation, the time occupied by its deposition must have been enormous.

It contains numerous flints—generally in nodules, which may be either scattered or arranged in lines, sometimes in continuous bands, which are occasionally oblique or even vertical. These therefore must be posterior to the rock itself. The nodular flints consist of silica, generally deposited round sponges, shells, or some other organic particles, which served as nuclei. In Kent the Lower Chalk has generally few or no flints; in the Middle Chalk they are scattered; in the Upper generally arranged in layers. These differences, however, are only local. In Yorkshire the upper part of the Chalk contains no flints. When we consider that flints do not form one-twentieth part of the whole rock, and remember the immense beds of flint gravel and shingle in the Thames valley, along our south coast, and elsewhere, we can faintly realise how enormous the destruction of Chalk must have been. The Chalk forms our beautiful Downs, the Chiltern Hills, Salisbury Plain, Beachy Head, the Needles, Flamborough Head, and the white cliffs of Old England.

A bold escarpment of Chalk sweeps round the

great oval of the Weald, from Eastbourne, by Lewes and Steyning, west of Petersfield, turning north to Farnham, Guildford, north of Reigate and Sevenoaks to near Folkestone, constituting in fact the boundary of the district. Most of the railways traverse it in tunnels. Nevertheless, though the escarpment is so continuous, it is cut through by the principal rivers of the Weald—the Medway, the Darenth, the Mole, and the Wey on the north; the Arun, the Adur, the Ouse, and the Cuckmere on the south. This seems at first very difficult to explain, and the lesson it teaches will be considered in a later chapter (p. 363).

The Chalk Downs form high ground, with beautiful short springy turf, on which it is a pleasure to walk; and a fresh crisp air, which it is a blessing to breathe. The distance from which they can be seen, the boldness of the slopes, and the contrast between the white chalk and green turf, have given the idea of cutting gigantic figures on several of the hillsides. The most celebrated is the one which has given its name to the Vale of the White Horse at Uffington. The giant of Cerne Abbas and the cross of White Leaf Hill may also be mentioned.

There is reason to suppose that during part at any rate of the period the climate was one of considerable severity.[1]

TERTIARY

The Tertiary strata are divided by geologists into four groups in descending order—

[1] *Mem. Geol. Surv.*, Cambridge.

Pliocene.
Miocene (wanting in England and Wales).
Oligocene.
Eocene.

The terms were suggested by Lyell and Deshayes with reference to the proportion of animals (especially Molluscs) then living, and which have survived to present times, Eocene being derived from two Greek words, and implying the dawn of existing life; Oligocene indicates that the strata contain a few, Miocene more, and Pliocene a still larger proportion, of our existing species. The strata comprise clays, sands, and gravels, indicating shallow seas and the mouths of large rivers.

They are characterised by the presence of large Mammals, among which species allied to our Tapirs, Elephants, and Rhinoceroses are specially remarkable.

The Tertiary strata are about 3000 feet in thickness.

EOCENE

The Eocene deposits of England occupy two distinct basins—those of London and of Hampshire; they were, however, originally continuous, and the elevation which led to their separation did not take place till long afterwards. The fossil remains indicate a tropical, or at any rate a warm, climate. The beds attain a thickness of about 2500 feet, and in descending order are divided into—

Bagshot, Barton, and Bracklesham Beds.
London Clay.
Oldhaven and Blackheath Beds.
Woolwich and Reading Beds.
Thanet Sands.

The Thanet Sands were so named by Sir J. Prestwich because they are well developed in the Isle of Thanet. They are yellow sands, sometimes with a tinge of green, and are a marine deposit, indicating a sea of moderate depth. They are well seen in the cliffs of Pegwell Bay and east of Herne Bay, at Erith, at Charlton near Woolwich, at Loam Pit Hill, Lewisham, etc. The sand is sometimes used for casting purposes.

The Woolwich and Reading Beds consist of mottled clays, loam, gravel, and sands of various colours. They are sometimes consolidated into a hard puddingstone, as at Newberries and other places in Hertfordshire. At Woolwich they are estuarine, and become more marine towards the east. In some places, as at Hungerford, Bromley in Kent, Charlton, etc., the base of this series is a regular oyster-bed (*Ostrea Bellovacina*).

The Oldhaven and Blackheath Beds consist of well-rounded shingle and sand. They contain marine and estuarine Molluscs, and from their being so thoroughly rolled Whitaker has suggested that they formed a bank some distance from the shore. They are well shown at Bromley, Blackheath, Greenwich, Woolwich, Rochester, Canterbury, etc.

The London Clay, on which so much of London is

built, is a brown or bluish clay, with calcareous nodules or septaria, and as much as 500 feet in thickness. It is a marine formation, indicating a sea perhaps 100 fathoms in depth, near the mouth of a great tropical or sub-tropical river. Among the more interesting fossils are various fruits, especially of Palms, Mimosas, Acacias, Euphorbias, etc.; and among animals a Sea-snake, probably about 15 feet in length, a Crocodile, several Turtles, Birds, and Mammals, some of them allied to the modern Tapirs. Monkeys also make their appearance. The Clay extends over parts of Norfolk and Suffolk (though not at the surface), Essex, Hertfordshire, Middlesex, Berkshire, Surrey, Kent, and Sussex to the Isle of Wight. It is much used for bricks, tiles, pipes, and sometimes for coarse pottery.

The Bagshot Beds are of fresh-water and marine origin. They correspond to part of the great Nummulitic formation of Southern Europe, so called from the large flat Foraminifera which resemble pieces of money (*nummus*), and are so abundant in some of the layers.

The celebrated Bovey Tracey Beds of Devonshire belong to this period, as do the plant beds of Bournemouth, which contain species of Ferns, Palms, Sequoia, Araucaria, Eucalyptus, Vines, Laurels, Fig-trees, etc. The Barton Clay is also rich in fossils, including Zeuglodon, the earliest known Cetacean.

The brilliant and varied sands—white, yellow, and crimson—of Alum Bay, which are rendered so

much more conspicuous from their vertical position, belong to this period. The Bagshot Sands cap also several well-known hills, as for instance Hampstead, Highgate, High Beach, and St. Anne's Hill; to them also we owe many of our beautiful Surrey commons.

The Lower Tertiary strata no doubt formerly extended far beyond their present boundaries. Outliers are found here and there on the Chalk Downs; and the Sarsen stones of Salisbury Plain are probably indurated masses of sandstone from beds of Bagshot Sand, the softer portions of which have been washed away. The Megalithic remains of Avebury, Wayland Smith's Forge, Kit's Coty House near Maidstone, and the outer ring of Stonehenge are formed of these Sarsen stones or Grey-wethers. The Altar Stone of Stonehenge is, however, a grey, micaceous sandstone, "possibly Old Red Sandstone from the neighbourhood of Frome; while most of the stones forming the inner circle are Diabase, and others are Felsites, Hornstones, and Schists, whose source is not known.[1] Sir A. C. Ramsay has stated that these are certainly not drifted boulders; and without asserting that they came from Wales or Shropshire, he observes that they are of the same nature as the igneous rocks of part of North Pembrokeshire, Carnarvonshire, and of the Llandeilo Flag district of Montgomeryshire, etc., west of the Stiper Stones."[2]

[1] N. S. Maskelyne, *Proc. Geol. Assoc.* vol. vii. 1881-82.

[2] *Mem. Geol. Surv. Wilts.* H. B. Woodward, *Geol. of England and Wales.*

Taken as a whole, we cannot but be struck by the fact that the fossils of the English Eocene beds contain representatives of species now found in widely distant regions. For instance, they contain Crocodiles, Alligators, and Gavials, which are never now associated together;[1] and among plants Eucalyptus and other Australian forms, with the Sequoias of North America, and other groups now typical of our own and the South European flora.

The early Tertiary period was one of considerable volcanic activity in the Hebrides. The basalt of Fingal's Cave in Staffa and that of the Giant's Causeway belongs to it, as well as possibly some of the eruptive dykes in the North of England; while, in the opinion of Teall, the Cleveland Dyke, which appears south of Whitby, and extends westwards for 90 miles, belongs to the Miocene.

OLIGOCENE

The Oligocene strata occur only in Hampshire and the Isle of Wight. They consist of thin beds of sands, clays, marls, and limestones of marine, estuarine, and fluviatile origin. A good general view of the beds is obtained at Alum Bay, near the Needles. The Oligocene rocks are about 600 feet thick in England, but in the Paris basin and Switzerland they are much more important.

[1] Nicholson and Lydekker, *Man. of Palæontology.*

MIOCENE

No strata of Miocene age have yet been determined in England.

PLIOCENE

The Pliocene period is illustrated principally by what are known as the "Crag" deposits of Norfolk and Suffolk. They consist of shelly sand, gravel, and clay. They are generally divided into—

Newer Pliocene.	Norfolk Forest Bed Series. Norwich Crag. Red Crag.
Older Pliocene.	Coralline Crag.

Patches, supposed to be of "Crag," have also been found at Lenham near Maidstone, and at Folkestone. Moreover, the surface of chalk is in many cases pitted by hollows or pipes, due to the action of rain-water, which at first accumulates in any slight hollow of the surface, and, by degrees dissolving away the chalk more and more, forms deep pipes, which are gradually filled in by the superincumbent strata. Some of these pipes near Guildford have been found to contain sand and gravel which appear to belong to this period. It is still more interesting that beds of the same age have been found by Cornish and Harmer at St. Erth, near the Lands End.

The "Crags," however, are not, as their name seems to imply, hard rocks, but the word is a local name, signifying a mass of loose gravel and sand, with comminuted shells.

The Pliocene strata are rich in Mammalian remains, among them being the great sabre-toothed Lion (*Machairodus*), Hippopotamus, Mastodon, Elephants (*E. meridionalis* and *E. antiquus*), Rhinoceros, Wild Horse, the Great Beaver, and Gazelle (*Gazella anglica*).

Judging from the Corals, the great Mammalia, and other fossils, the climate at the commencement of the period would seem to have been subtropical.

The celebrated Cromer Forest Bed on the Norfolk coast, which is only exposed at low-water, must obviously have been at some little height above the sea-level, and probably some distance from the coast, at the time when the trees grew.

That Britain was once united to the continent was long ago inferred from the similarity of the chalk cliffs at Dover and Calais; while Verstegan in 1605 drew the same inference from the occurrence of the wolf, for "no man would ever transport any of that race out of the continent into any isles."[1]

It is probable, when the country stood at a somewhat higher level than at present, that the German Ocean and English Channel were dry land, that the Thames and the Rhine ran over the great plain now occupied by the North Sea, and emptied themselves into the Arctic Ocean, and that most of our land animals then found their way into England. It is also probable, but not certain, that man arrived with them.

[1] *Restitution of Decayed Intelligence in Antiquities concerning the English Nation*, 1628.

CHAPTER II

THE QUATERNARY PERIOD

There rolls the deep where grew the tree,
O earth, what changes hast thou seen!
There where the long street roars, hath been
The stillness of the central sea.

The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist; the solid lands,
Like clouds they shape themselves and go.

TENNYSON.

THE time which has elapsed since the close of the Tertiary, is known as the Quaternary period; this name was suggested by Morlot in 1854. The strata comprised in it are far less in point of actual magnitude, and imply a far smaller lapse of time, than those of the preceding periods. On the other hand, they are important from at least three points of view: they occupy much of the surface, and exercise therefore a direct influence on agriculture; for the same reason they have an effect on the scenery out of all proportion to their thickness; and lastly, they are interesting as having afforded

the earliest undoubted evidence of the presence of man.

The beds comprise widespread but irregular accumulations of clay, loam, gravel, and sands, and their total thickness is less than 500 feet—not however, all reaching, or at least retaining, their full development at any one place.

During parts at any rate of the Tertiary period the climate appears to have been decidedly warmer than at present. This is indicated by the Palms, Crocodiles, and great Serpents of the London Clay; but gradually the temperature sank, and we come to a time which from the great cold is known as the Glacial or Ice Age. This cold condition (though probably with mild intervals) prevailed during a great part of the Quaternary period.

After the Eocene period England appears to have been for a long time above the sea-level. During the Miocene, the whole country appears to have been above water, and this continued during the Pliocene, except as regards a part of our eastern counties.

Then, however, came a period of depression. This is generally admitted, but as to the amount of subsidence there is much difference of opinion.

Trimmer discovered in 1831, at a height of 1250 feet, on Moel Tryfaen, about 5 miles south-east of Carnarvon, a bed of sand and gravel some 35 feet thick and containing marine shells of existing species. Again, in Cheshire near Macclesfield, Sir J. Prestwich found similar marine shells, sand, and gravel at a height of 1200 feet. This evidence was long and

generally accepted as proving a submersion to that extent. Nevertheless, in that case it might have been expected that the evidence would have been more widespread. The shells, moreover, are in a very fragmentary condition; coast species are mingled with those inhabiting deeper water; and Mr. Goodchild has therefore suggested that the great ice-sheet which, as we shall presently see, came from Scotland and extended far over North Wales and the centre of England, tore up portions of the sea-bed and carried them far inland. This explanation also presents great difficulties; and though it is that to which the weight of geological opinion appears now to tend, the question cannot be regarded as finally determined.

On the other hand, there is strong evidence of a relative subsidence, say to 400 or 500 feet; this is inferred from the wide distribution of marine gravels containing shells which belong to northern and arctic species, indicating that the climate was much more severe than at present, and that our seas contained many icebergs.

Then came another period of elevation, and the land was raised to a relative height of at least 200 feet above the present level. The varying conditions resulting from these changes account for the varying structure of the drift deposits. The climate had gradually become very cold, and our northern counties, with the exception of the highest mountain-tops, were covered by a great ice-sheet, as Greenland is now.

THE GLACIAL PERIOD

The Swiss geologists, and especially Agassiz, had long ago shown that the Swiss glaciers once extended far beyond their present limits. This was proved: (1) by the presence of rocks rounded, furrowed, striated, and polished by ice, which were called by De Saussure *roches moutonnées* (Figs. 5-7, pp. 50-53), not however so much from the rounded outlines as from the crinkled surface, resembling the woolly texture of a sheep's back; (2) by the presence of moraines; and (3) by "erratics" or blocks of stone (Fig. 17, p. 71), often of great dimensions, and now lying far from their place of origin. These evidences of ancient glaciers extend over all the lowlands of Switzerland, and even farther, as, for instance, to Lyons.

Agassiz, on a visit here in the year 1840, naving observed the presence of similar indications in England and Scotland, suggested to Dr. Buckland the former existence of extensive glaciers in the British Isles. Buckland carefully examined many parts of the country, and clearly proved that not our mountain regions only, but a great part of the lowlands also, as far south, at any rate, as the valley of the Thames, were once covered by a thick mantle of ice; that, in the words of Sir A. Ramsay, "England north of the Thames valley has been actually moulded by ice."

It is probably impossible for any one who has not seen glaciers to realise what they are really like.

The snow which falls in cold countries and in sufficiently mountainous regions passes by the slow action of pressure and the percolation of water gradually into ice. This may cover the whole or almost the whole country, as in Greenland; or descend the valleys in long rivers of ice, as in Switzerland.

Our climate is now too genial to admit of the formation of glaciers, but the former existence of a colder period is clearly proved by—

1. Ground and polished rock surfaces.
2. Moraines.
3. Drift.
4. Animal and vegetable remains.
5. Erratics.

GLACIATED ROCKS

The ice of glaciers often attains a thickness of many hundred or even some thousands of feet; and as it contains many hard pieces of rock, it grinds, smooths, and scratches the beds over which it passes.

Scandinavia was covered with a sheet of ice, which has ground down even the highest mountains, reducing them to rounded domes.

In Switzerland the loftiest summits stood out above the ice-level. They have therefore remained as sharp and pointed peaks. Hence the different aspect of Norway and of Switzerland. In the latter the upper level of the ice is often sharply marked. De Saussure long ago observed that in the Swiss valleys

there was often a well-marked line, above which the rocks were angular and jagged, while below it

DIAGRAMS TO ILLUSTRATE THE FORMATION OF *ROCHES MOUTONNÉES.*

Fig. 3.—Original form of Ground.

Fig. 4.—Do., after being smoothed by the action of a Glacier.

they were smooth and rounded; but he did not

Fig. 5.—View of the Grimsel.

suggest any explanation. By some it was referred to a difference in the character of the rocks. Desor,

Fig. 6.—Glaciated Rock, Capel Curig, North Wales.

however, satisfied himself that no such difference occurred, and suggested the true explanation, namely, that the lower smoothed hummocks had been covered and ground down by the glacier, while the upper jagged, serrated portion rose above, and had not therefore been subjected to the action of the ice.

It is easy to see how these rounded and polished surfaces would be produced.

Let Fig. 3 represent the rugged surface of a country over which a glacier is passing from the left to the right. The stones under the glacier, pressed down by the weight of the ice, will gradually abrade the surface (Fig. 4) and reduce it to smooth curves, while the sheltered surfaces will scarcely be affected, and the debris will be deposited in the hollows. Rocks so rounded not only indicate the action of ice, but also the direction in which it was travelling; for it is evident that the gentle slope will be on the side which faced the ice, and the steeper side on the lee.

Smoothed and polished rocks occur also "many-where," if I may coin the word, in our northern districts, where the rocks are hard enough to receive and retain their characteristic marks.

Fig. 5 is a view of the Grimsel in Switzerland, a good typical instance of glaciated rocks, which I have given for comparison with similar scenes in our own country. Fig. 6 represents a glaciated rock near Capel Curig, and Fig. 7 the typically glaciated scenery near Glaslyn in North Wales.

No one who compares Figs. 6 and 7 with Fig. 5

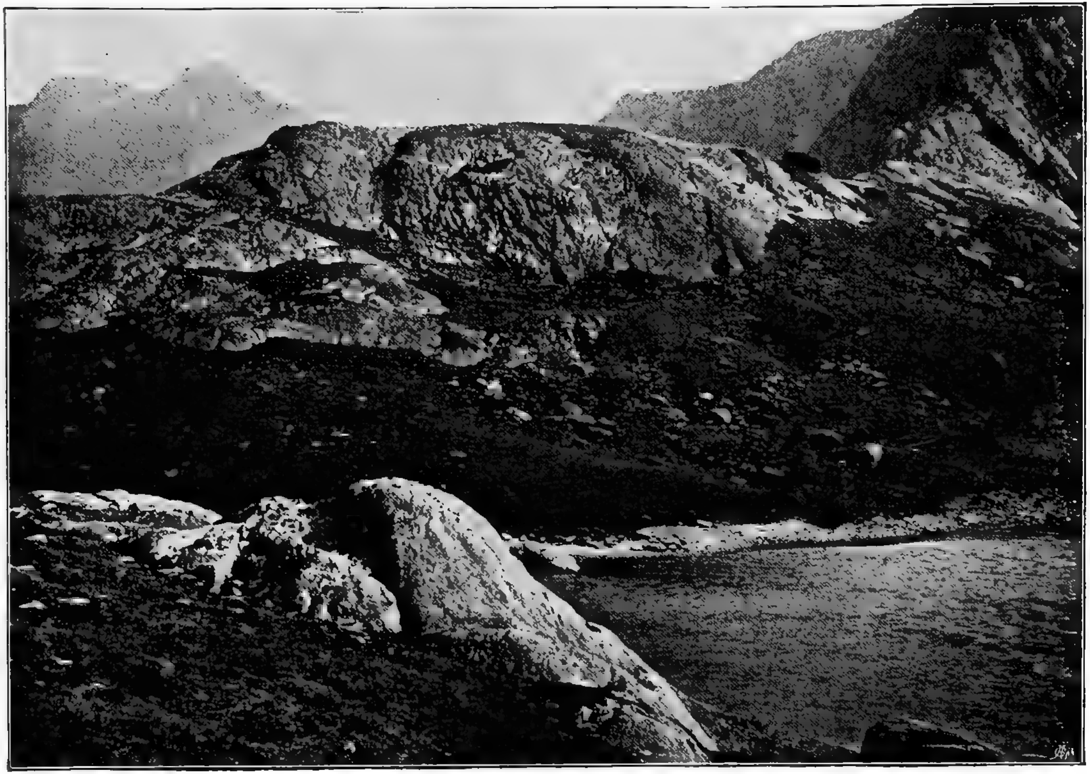


Fig. 7.—Glaslyn, North Wales.

can entertain a shadow of a doubt that the latter also represents rocks which have been ground by the action of ice. Fig. 8 is more magnified, and shows, near the spot marked with a ×, the actual grooves on a glaciated rock in Ambleside Churchyard, which is classical from having been long ago described by Sir Charles Lyell.

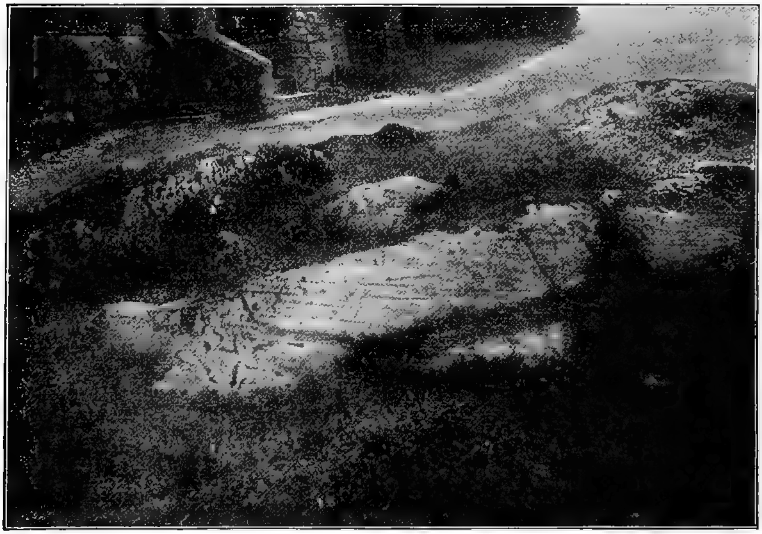


Fig. 8.—Striated Rock in Ambleside Churchyard.

On surfaces which have been long exposed the striæ are generally obliterated; but when just stripped of turf or drift, or when under water, the rocks are generally found to be smoothed and striated.

That these striæ are due to an ice-sheet, and not merely to local glaciers, is clear from the fact that they often occur on the highest points, as, for instance, on the summit of Bowland Knotts (1400 feet), where

they run S. 15° E. across the ridge. Tiddeman has also brought forward strong evidence that in North Lancashire the glacier was sufficiently thick and powerful to ignore the hills and valleys which lay in its path.

Fig. 9.—Form of Scratch.

The scratches themselves often resemble a headless pin, pointed at one end, broader

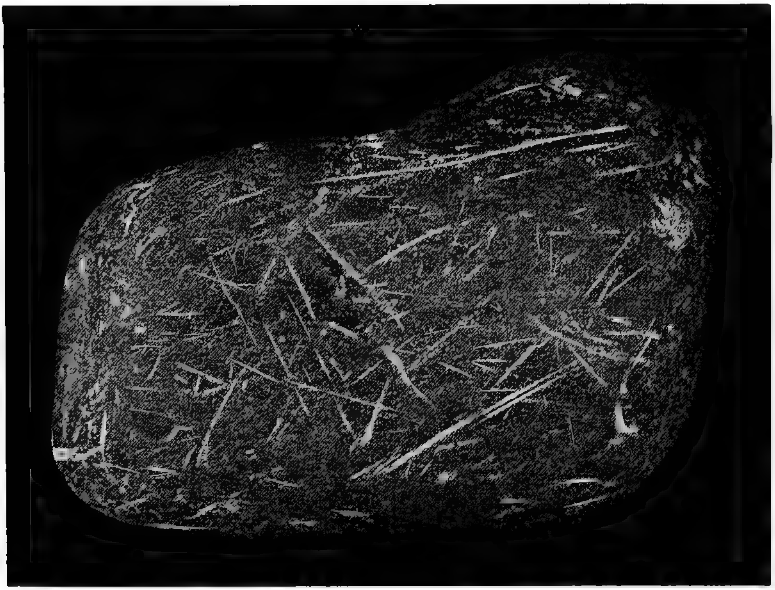


Fig. 10.—Scratched Pebble from a Moraine.

and deeper at the other. In such cases the direction of movement has been from the pointed to the broad end.

The stones in moraines are also often much scratched. One is shown in Fig. 10.

MORAINES [1]

The mountain-sides which surround glaciers shower down on them fragments, and sometimes

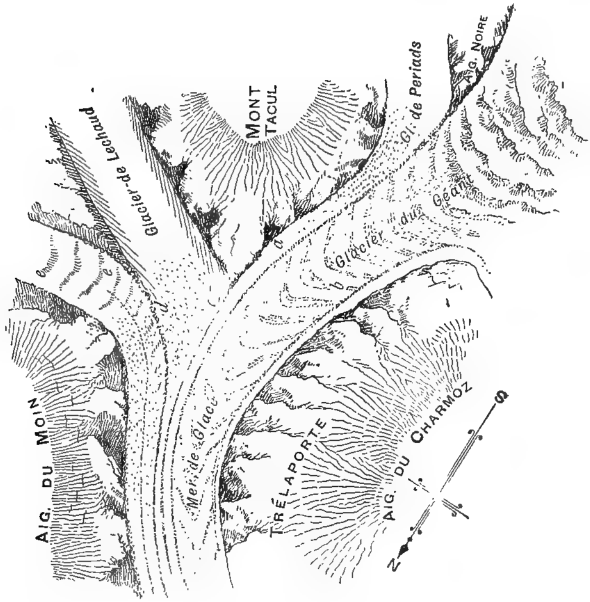


Fig. 11.—Sketch-map of the Mer de Glace, and contributory Glaciers.

immense masses of rock, which gradually accumulate at the sides and at the end, thus forming ridges, which are known as "Moraines." When two glaciers meet, a "medial" Moraine is formed by the union of two "lateral" Moraines (Fig. 11), while the matter carried along under the glacier is known as "ground Moraine." However many glaciers may unite, the Moraines keep themselves distinct, and may often be

[1] "The word 'moraine' was adopted by Charpentier from the local name used in the Valais, and has now become general."

seen for miles stretching up the glacier like lines side by side.

A Moraine is a mass (Fig. 12) of stones and mud, with a confused, undulating, hummocky, pitted surface, sinking into shallow hollows and rising into irregular mounds.

Fig. 12.—Section of Morainic Mass in Borrowdale.

Both terminal and lateral Moraines occur in many of the valleys of our mountainous regions: in North Wales, by the side of Llyn Llydaw on Snowdon, between Cwm Glas and Blaen-y-nant; again near Nant Ffrancon, in Llyn Idwal (first described by Darwin in 1842); in the Pass of Llanberis; and in many other places. The wooded mounds in Penrhyn Park are also Moraines, and there is a very fine one near Ellesmere.

Among the most important in the Lake District are those in the Rosthwaite alluvial plain, in Borrowdale under Wolf Crag, in Greenup Gill,[1] at the head of Ennerdale, and in Langstrath.

The lateral Moraine of the great Ribblesdale glacier can be "traced past Skipton on to Rumbles Moor at an elevation of 1175 feet south of Ilkley, where, under various names, such as 'Laneshaw Delves,' 'Skirtful of Stones,' 'Long Riding,' etc., it surmounts the tongue of ice on the moor and, bending southward, crosses the Aire at an elevation of 600 feet below Bingley."[2]

Speaking of the Moraine at Fountains Abbey, Carvill Lewis says that "nature and art have combined to make the Moraine more beautiful here than anywhere else in Great Britain. Fountains Abbey itself stands close to the non-glaciated area, and the bare rocks bound the ravine in which it stands. East of the Abbey, still in its grounds, the graceful Moraine hummocks suddenly rise and block up the valley, forming the curves that, by the aid of art, are such lovely features of the landscape."[3]

York is built on the terminal Moraine of the great glacier which, as we shall see, came from the South of Scotland over the Irish Sea; while in Holderness and near Flamborough Head is the terminal Moraine of another great glacier, which came from Scandinavia across the North Sea. This blocks out the River

[1] Marr, *Scientific Study of Scenery.*

[2] Carvill Lewis, *Glacial Geology of Great Britain.* [3] *Ibid.*

Derwent from the sea, and compels it to take its roundabout course to the Humber.

GLACIAL DRIFT

But the most extensive deposits due to ancient glaciers are the enormous sheets of "Drift" which,

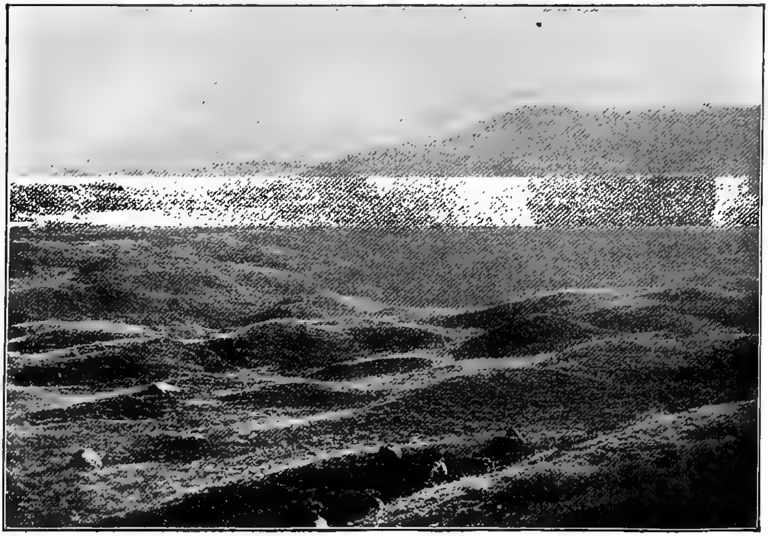


Fig. 13.—Morainic Mounds, Honister Pass.

as far south as the Thames valley, cover a great part of the country, with the exception of the highest mountain-tops.

The Drift often forms sheets, at other times more or less irregular mounds. Fig. 13 represents a group of drift or moraine mounds on the summit of Honister Pass, between Derwentwater and Buttermere.

They (Fig. 13) consist of clay, sand, and stone,

mixed irregularly, often almost without stratification, or any reference to size.

Such deposits were evidently left on their present sites by the glacier itself. As we see in Switzerland, the ice which melts on the glacier flows out from the lower end, sometimes in a single stream under a beautiful arch of blue ice, sometimes in many streamlets, which frequently alter their course; and the result is that the glacial deposits are often more or less rearranged by water, and such beds are known as "fluvio-glacial" deposits, or shortly as "Drift."

As glaciers often retreat and then advance again,

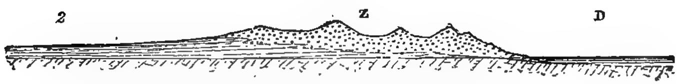


Fig. 14.—Glacial Deposits. D, Site of ancient Glacier; Z, Moraine; 2, Fluvio-glacial Deposits.

the cone of transition in many cases presents alternations of true morainic and fluvio-glacial strata.

When the glacier retreated, the water often occupied the central depression between the ice and the moraine, forming a lake. In most cases, however, the stream cut by degrees through the moraine, and drained the lake. The streams then wandered over the old glacier bed, and spread out the moraine matter which had been brought down by the glacier.

Fluvio-glacial deposits are therefore composed of the same materials as moraines, and indeed only differ in being more or less rolled, and rearranged by water, like river gravels. They are glacial deposits caught up and carried to a greater or less distance by water.

Such deposits and Drift are therefore in intimate relation; they agree in their composition, and differ only as regards stratification. The fluvio-glacial beds, as we come nearer and nearer to their source, are composed of larger and more angular pebbles, while the stratification becomes less and less regular, so that they approximate more and more to the character of true moraine. Some again have no doubt been reassorted by marine action, especially those at low levels.

River gravels also sometimes contain great blocks of stone (Fig. 15), which can hardly have been moved into their present position except by the action of ice.

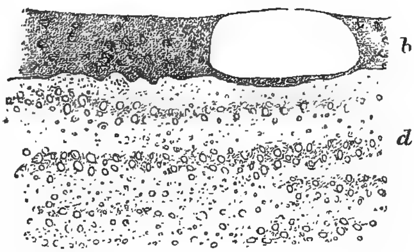


Fig. 15.—River Gravel containing a Stone Block. *b*, Loess; *d*, Gravel.

The surface of a true glacial deposit (Fig. 13) is irregular, and presents a succession of hills and valleys, often more or less concentric in outline, and enclosing a central depression (the site of the glacier itself), so that it forms a sort of amphitheatre.

Such deposits are as a rule more or less gravelly and sandy, but a large portion of our English Drift consists of a very stiff clay, containing numerous scratched stones, whence it is known as "Till" or "Boulder-clay."

It differs greatly in character in different parts of the country, and generally much depends on the character of the neighbouring strata, especially

those to the north-west. In the neighbourhood of Chalk it often contains great masses of that rock. Over Kimmeridge Clay it is mainly composed of Kimmeridge Clay, over Oxford Clay of Oxford Clay, and so on.

In many cases, as for instance on the Norfolk

Fig. 16.—Contorted Drift near Cromer.

coast, the Drift beds are much contorted (Fig. 16). This may be in some cases due to their having been crumpled up by glaciers or icebergs during the period of depression; in others, as suggested by Trimmer, to the melting of large included masses of ice which have let down the overlying beds. Again, the Boulder-clay often contains great blocks of chalk. These are continually being dissolved by the percolation

of rain-water, and this again would tend to produce the same result. Moreover, in Arctic countries, like Siberia, the soil is permanently frozen, and only the upper part thaws in summer. As the rain cannot sink into the frozen soil, the melted cap becomes saturated with water, and is converted into a sort of sludge, which readily slips from the high ground, and becomes crumpled up and squeezes itself into any depressions.

The Drift deposits often attain a considerable thickness: near Skipton 114 feet, near Prestwich 150, about Ashton 174, in Lanchester Valley 222, in Rutland as much as 300 feet, and in parts of East Anglia as much as 400 feet.

Over a great part of the Midlands the Boulder-clay and Drift filled up the older valleys, and when the glacial conditions passed away the streams had to excavate new channels for themselves.

The surface of the Drift is often very uneven, and has a tendency to form low hills, which are often the original heaps in which the material was deposited, and not, like hills of solid rock, remnants of an elevated mass, which have escaped denudation.

There is no difference of opinion that Boulder-clay is matter which has been more or less ground up by glaciers, often indeed reduced to a fine impalpable powder, known in Switzerland as "flour of glaciers"; but there has been some doubt whether it is ground moraine formed on dry land, or under water, or whether it was deposited by icebergs.

In the West of England the Boulder-clay frequently

contains marine shells; and as these often contain fine sand, they have evidently been brought from a greater or lesser distance.[1] At this period the land probably stood considerably below its present relative level, so that a great part would be under water. Moreover, in any case the great Galloway glacier, with its load of Scotch rocks, came, as we shall see, across the Irish Channel.

The Boulder-clay often shows marks of great compression. In Holderness one block of sandstone, originally a yard or more in diameter, has been split up, and the pieces dispersed over a surface of about 20 square yards. Clement Reid aptly compares them[2] to the fragments of a stone over which a steam-roller has passed.

In some cases great masses of rock have been taken up and carried by the ice to considerable distances. In other places we find the underlying rocks, as for instance the upper layers of the Chalk near Trimingham and Whitlingham in Norfolk, thrown into great folds. Reid remarks[3] that the result is like that of a tablecloth creased by a heavy book being pushed over it. A further stage might be the shearing off of the projecting bosses,—this would account for the immense masses of rock sometimes found embedded in the Boulder Clay.

In the Stoke cutting, south of Grantham on the Great Northern Railway, the Boulder-clay was found

[1] See, for instance, Shone, *Quar. Jour. Geol. Soc.* vol. xxxiv. 1878.
[2] *Mem. Geol. Survey*, Holderness.
[3] *Mem. Geol. Survey*, Cromer.

to contain a mass of Oolite 430 feet long, and in one part 30 feet deep. At Eston Hill a strip of Cleveland Ironstone, some 150 yards long, 50 broad, and 11 deep, has been bodily lifted up the face of the hill to a point about 150 feet above its natural outcrop.[1] Near Sheringham is a detached mass of Chalk 300 yards long. In Roswell pit, near Ely, there is a mass of Chalk, Greensand, and Gault 430 yards long and 60 wide. Masses of similar origin have been found at Sywell in Northamptonshire, at Ridlington in Rutlandshire, at Stukeley in Huntingdonshire, and elsewhere.

The Boulder Clay spread south to the brow of the Thames valley, beyond which, however, it has not yet been found.

ESKERS OR KAMES[2]

The Drift is generally deposited in sheets, or is plastered against the rocks and hillsides. In some cases, however, it forms long low ridges and mounds, which are known as Kames in Scotland, Eskers in Ireland, and elsewhere as Drums or Drumlins.

The famous Mote Hills of Elsdon in Northumberland—fine defensive earthworks probably of British origin—are Eskers which have been modified into their present forms.[3] There are several between

[1] Ramsay, *Phys. Geol. of Great Britain.*

[2] Perhaps from the Gaelic "cam," curved or crooked. Mr. Campbell of Islay has suggested "coom," a path.

[3] *Mem. Geol. Surv.*, Otterburn.

Lucker and Bamburgh, and again between Alnwick and Berwick. Another, known as Blake Law, south of Cornhill, rises to 130 feet on the north and 100 on the south above the surrounding ground. One at Wark has a length of 1400 yards, with a height of about 30 feet.[1] In the Lake District there are a number between Head's Nook and How Mill, near Carlisle, and on Windermere, as for instance the mounds near Storr's Hall and the Flagstaff Hill. They also occur on the western slopes of the Lancashire moorlands.

Carvill Lewis considered that the finest Esker seen by him in England was one near the railway station at Durham. In Yorkshire one of the most important is the long curved mound of Brandsburton, which has yielded remains of the Mammoth.[2]

In East Anglia there is a large one near Hunstanton. They do not seem to occur in the South of England.

Eskers are found at various levels, up to a height of 800 feet. They vary much as to the coarseness or fineness of the materials of which they are composed. They may form isolated mounds and ridges, or may occupy a compact area of country. In some parts they are parallel, and so numerous that the country has been happily described as "fluted." They are often[3] more conspicuous than their mere height above the sea would make them,

[1] *Mem. Geol. Surv.*, Parts of Northumberland.
[2] Phillips, *Yorkshire.* [3] *Mem. Geol. Surv.*, Carlisle.

from the contrast of their steep sides with the low and gentle undulations of the earthy gravel, from the irregularity of their occurrence, and their generally unique appearance.

Another striking peculiarity of Eskers is their remarkable distribution, sometimes on comparatively high ground, generally running along, but sometimes diagonally across, the valleys in which they lie. They are so conspicuous, so curiously arranged, and keep so green both in summer and winter, that they are popularly supposed to be the work of elfin hands, and to be inhabited by the fairies.

Geologists are not yet agreed as to their origin, and they are not perhaps all due to the same cause. The most probable explanation seems to be that they occupy the sites of hollows in glaciers worn out by subglacial streams and then filled or partly filled with gravel. The current bedding shown by Eskers points to deposition in running water. The sides are steep, which points to the existence of a supporting wall of ice, which prevented the water from spreading out the materials. Professor Sollas[1] has happily termed them "casts" of river-beds. This accounts for the fact that while they have a tendency to follow the direction of the valley in which they lie, they sometimes run diagonally, or almost directly, across them.

[1] *Rep. Brit. Assoc.* 1893.

THE EVIDENCE AFFORDED BY ANIMAL AND VEGETABLE REMAINS

Another line of evidence which proves the former existence of an Arctic climate in these islands at a recent geological period, is that afforded by the animal and vegetable remains which are found in the Drift and river-gravel deposits.

In 1855 Kingsley and I discovered in the great gravel-pit at Maidenhead part of the skull of a Musk Sheep, the most Arctic of Mammals, which is now confined to Arctic America and Greenland. It was the first found in Europe, but remains have since been discovered in other parts of England and on the Continent. With it are associated most of our existing species, and in addition the Reindeer, the Glutton, the Marmot, the Arctic Fox, the Elk, Norwegian Lemming, the Siberian Mammoth, the Woolly-haired Rhinoceros, the Snowy Owl, etc., while the Molluscs also indicated a cold climate.

The vegetable remains tell the same story. We find the Arctic Willow (*Salix polaris*), the Arctic or Dwarf Birch (*Betula nana*), and many other plants which now only flourish in the far North or on the summits of high mountains.

But it is very remarkable that with the above-mentioned species occur others of very different characters: firstly, some which indicate warm rivers and

luxuriant vegetation,—especially a Hippopotamus[1] which cannot be distinguished from the existing African species, and which then lived in England with a fresh-water Mollusc, the *Cyrena* (*Corbicula*) *fluminalis*, just as the same mollusc and the same quadruped now live together in the African rivers; and secondly, a group of animals not so familiarly known to us—the Steppe Marmot, the Steppe Antelope, Steppe Porcupine, Jerboa, etc., which now live in the dry deserts of Central Asia. The evidence, in fact, all points to the existence of three different climates: (1) glacial; (2) warm or subtropical and moist; (3) dry and desert conditions.

Morlot was, I believe, the first to point out that the Arctic conditions were not continuous, but were interrupted by at least two intervening warmer periods. In England we often have two beds of Boulder-clay, as was first observed by Joshua Trimmer,[2] separated by one of sand or gravel. This is the case in Cheshire, Lancashire, and Shropshire, as well as in the central districts and in East Anglia. It by no means follows, however, that these beds in different localities correspond to one another. Gravels of the same age may therefore lie over Boulder-clay in one place and under it in another. Skertchly considered that in East Anglia there are four distinct beds of Boulder-clay, separated by gravel and sand, and indicating four periods of cold.[3] James Geikie

[1] Found as far north as Lancashire, where Leigh discovered a skull as long ago as 1700.

[2] *Proc. Geol. Assoc.* vol. ix. 1885-86.

[3] *The Fenland.*

maintains that in Scotland the oscillations were even more frequent.

ERRATICS

I now come to the fifth class of evidence which proves the existence of an Arctic climate and the former extension of glaciers. I have left it to the last, because it not only supports the conclusion derived from the previous considerations, but also enables us to determine approximately the former extension of, and course adopted by, the Ancient British glaciers.

The stones and rocks which occur in Boulder-clay comprise ordinary flint, peculiar red flints, gneiss, mica-schist, hornblende schist, hard sandstone or grit, carboniferous limestone, diabase, porphyry, felsite, porphyrite, and rhomb-porphyry. Many of them are from South Scotland, the Lake District, and Wales; but some, and especially the three last, are Scandinavian. The rhomb-porphyry is a very peculiar and characteristic rock which occurs near Christiania.[1] The red flints also are unlike any English specimens.

Moreover, in addition to these hand specimens, we find scattered over much of our northern and central counties large unrolled blocks of stone known as "erratics" (Fig. 17), because they have wandered, often to a great distance, far from their original home.[2] In Switzerland many of these are so

[1] Reid, *Mem. Geol. Surv.*, Holderness.

[2] Other celebrated masses of rock have a different history. The so-called Sarsen stones of Wiltshire are probably the remnants of a sandstone bed of

Fig. 17.—Perched Blocks near Llanberis ; in the right-hand corner is a Glaciated Rock.

gigantic that they have struck the imagination of the peasantry, have been attributed to superhuman agency, and have received special names, such as the "Pierres de Niton" in the lake near Geneva, so called from a tradition that in Roman times sacrifices were offered upon them to Neptune. The "Pierre de Crans" near Nyon is 73 feet long and 20 high.

The "Pierre à Bot," near Neuchâtel, at a height of 2200 feet, is 62 feet in length, 48 in breadth, and 40 feet high. It is of Protogine, and probably came from the Mont Blanc range.

The English erratics, if somewhat smaller, are also very numerous and instructive.

There is an immense group about two miles E.N.E. of Clapham near Ingleborough, which I have had the advantage of visiting with Mr. Marr. The Limestone plateau is strewn with masses of Silurian grit, often 16 to 20 feet in diameter, and sometimes supported on pedestals 18 inches to 2 feet in height. Cheshire is remarkable for large and far-travelled boulders.

On Eddisbury Hill is a mass of the volcanic rock of the Lake District 10 feet × 5 × 4. One of the largest in North Wales is at Plas Wilkin, near Rhydymwyn. It measures 24 feet × 18 × 9, and is known as Y-garred-boeth, the hot stone, giving its name to a lead vein close by. Another at Erryrys

the age of the Bagshot Sands. The Agglestone, or Haggerstone, again, which stands about 18 feet high on a hill near Studland in the Isle of Purbeck, is an irregular weathered remnant of Bagshot Sands, and owes its preservation to the induration of the sands.

The Bowder Stone, near Derwent Water, which is 62 feet in length and 30 in height, has simply fallen from the heights above.

is 12 × 12 × 10. Near Burton in Shropshire there is a remarkable group, mostly from the Lake District, covering an area about a mile in breadth and a mile and a-half in length. Near Wolverhampton there is a truly wonderful concentration of granite blocks. They occupy an area about 15 miles in length and 4 in breadth, terminating quite abruptly. The total number, says Mackintosh, must amount to many thousands, and there must be some thousands of larger ones measuring more than 3 feet across.

The Blue Stone Inn at Louth is so called from a boulder which has been known for 400 years.

Charpentier,[1] and subsequently Guyot,[2] traced the course of many of the great Swiss erratic blocks, and pointed out that as they proceed from the place of origin they spread as it were in a fan, and that those from one district do not overlap those from another, as would be the case if they had been distributed by rivers or icebergs: for instance, those of the West Jura come from Mont Blanc and from the Valais, those of the Bernese Jura from the Bernese Oberland, and those of Argovie from the eastern cantons and the Rhine.[3] Not only are the blocks from each drainage area kept separate, but even, as a rule, those from the two sides of the same valley.

The same holds good with our English erratics. If they had been carried by water, they must have been much rolled; if they had been borne by icebergs, they would be dispersed so to say indiscriminately,

[1] *Essai sur les Glaciers.* [2] *Bull. Soc. Sci. Nat. Neuchâtel*, vol. i. 1847.
[3] Agassiz, *Etudes sur les Glaciers.*

or almost at random, over the Drift area. This, however, is not the case. Their deposition follows certain general rules. In Lancashire and Cheshire, for instance, they are always to the south or south-west of their place of origin. As Phillips first observed, they often occur at a height considerably above that of the parent rock. This seems at first sight a conclusive proof that they could not have been transported by icebergs, for on this hypothesis the parent rock must have been deep under water. Darwin[1] indeed ingeniously showed that on a shelving shore a certain number of blocks might have been raised by shore ice, little by little, season by season. Such cases, however, must be comparatively few, and the explanation could not account for the presence of thousands of blocks such as are found in the north and centre of England.

In these cases the erratics consist of a rock foreign to the district, and have been transported from a distance.

It is not, indeed, always possible to determine the locality from which they have been brought.

There are, however, some classes of erratic blocks which are of such special composition that they can be traced to their sources; of these five are particularly instructive, viz. the volcanic blocks from Arenig in North Wales, the Shap Granite, the Eskdale Granite from the Cumberland coast, the Galloway Granite from the South of Scotland north of the Solway Firth, and those from Scandinavia.

[1] *Quar. Jour. Geol. Soc.* vol. iv. 1848.

Part of the Granite from the South of Scotland travelled almost due east till the stream was broken by Cross Fell into two branches: one of them passed down the lower Tyne to Newcastle, the other was carried south up the Eden valley, meeting the stream of Lake District rocks, and with them passed over Stainmoor eastwards, until it was diverted by the Cleveland Hills, which sent one line down the Tees, and the other down the Ouse as far as, or rather farther than, York. The main stream of the Galloway Granite, however, travelled due south over the Solway Firth and on to the low shores of Lancashire and Cheshire. On the north coast of Wales it met the glacier from the North Welsh mountains, and was divided into two streams; one covered Anglesey, parts of Denbigh and Carnarvon, and extended as far as St. Davids Head. The other turned to the south-east, attained a height of 1450 feet in the Vale of Llangollen, 1200 at Macclesfield, and reached as far as Wolverhampton, where the end of the glacier seems long to have rested, and has left the marvellous collection of great blocks already mentioned.

The distribution of the Shap Granite is also very remarkable. Blocks of it have travelled over the Limestone ridge of Stainmoor (1800 feet at the pass), down the Vale of York, over the Oolitic ridge (1485 feet), and over the Chalk hills (800 feet) to Flamborough Head,[1] north of which they are said to be abundant.[2] Moreover, they appear to have entered

[1] Phillips, *Rivers, etc., of Yorkshire;* Buckland, *Proc. Geol. Soc.* vol. iii. 1838-42; J. G. Goodchild, *Quar. Jour. Geol. Soc.* vol. xxxi. 1875.

[2] *Mem. Geol. Sur.*, Bridlington Bay.

Yorkshire, not by the lower pass at Stainmoor (1400 feet), as they would have done if transported by water, but by the upper pass (1800), indicating that they were carried by ice.[1] Blocks of Shap Granite have even been dredged from an area known as the "rough ground," a few miles from the mouth of the Tees, which was probably a terminal moraine.[2]

A second less important but well-marked trail passes over the hills to the south, and down the valley of the Kent.

The rocks from the Arenig mountains in North Wales were transported mainly to the east and south-east. They have been traced as far as Evesham and Birmingham.

So far as the North of England is concerned we may say that, except the very highest portions,[3] all the western side of the country is covered with a sheet of Drift. The upper ridge of the Pennines, however, is bare or with local moraines. For a distance of from 10 to 20 miles on the east, again, the low grounds are almost free from glacial deposits, which, when present, are thin and patchy.

The explanation of this seems to be that the Drift coming from the north-west was banked up against the western slopes of the Pennines,[4] the upper parts of which seem never to have been covered, though the ice forced its way through some of the passes, and especially those on Stainmoor.

[1] Carvill Lewis, *Glacial Geol. of Great Britain.*

[2] Kendall, *Proc. Yorks. Geol. and Polytech. Soc.* vol. xii. 1891-94.

[3] And even these were perhaps covered by local ice.

[4] *Mem. Geol. Surv.*, North Derbyshire.

These circumstances point to the eastern Boulder-clay being mainly the product of Scandinavian glaciers, and hence containing Scandinavian rocks; while the western sheet was formed by the glaciers of Galloway, of the Lake District, and of North Wales.

On the east coast the deposits attain a considerable thickness, and, as already mentioned (p. 70), contain boulders of rocks which are only known to occur in Scandinavia. Towards the south the Boulder-clay has been to a great extent removed by denudation, but it occurs here and there as far as the northern edge of the Thames valley.

These converging lines of evidence prove that in the period of greatest cold Northern Europe, over an area of from 700,000 to 800,000 square miles, was buried under a vast sheet or mantle of ice, which was thickest in the north and west. Over parts of Scandinavia it was probably not less than 6000 feet in thickness, in North-West Scotland over 3000; the tops of the Cheviots, and the hill-tops of the West Riding 2300 feet high, are distinctly glaciated, as is also Wastdale Crag, near Shap, 1600 feet, whence the ice gradually thinned away to the south and east.

During the period of greatest cold the Scotch and Lake District glacier extended to, and even beyond, the Yorkshire coast on the east and beyond Wolverhampton on the south; while the great Scandinavian glacier occupied the North Sea from near Flamborough Head to the mouth of the Thames, and passing over the Lincolnshire Wolds pressed up the Trent valley past Nottingham and Derby as far as Burton-on-Trent.

The cold of the Glacial period accounts also perhaps for some of the dry valleys in the Chalk districts. In a climate like ours, the rain, as we know, sinks into the Chalk and the drainage is now subterranean. If however the snowfall was heavier and the cold more severe, the ground would be frozen, snow would accumulate, and when the spring thaw came there would be heavy floods rushing down these valleys, though it might be only for a few weeks in the year.

Evidences of ice action are not confined to Great Britain or to the continent of Europe. Similar conditions occur in North America. The Eastern Canadian highlands have been laid bare and glaciated, the loose materials having been carried south and spread out over the Northern and Central States in an immense sheet of Drift, which covers the rock floor sometimes to a great depth. North-West Ohio, for instance, as Davis points out,[1] has been converted from a region of hills and valleys into a smooth plain by a heavy covering of Drift, in many places over 100 feet thick, and averaging at least 30, over hundreds of square miles. The great glaciers seem to have retreated very slowly. In Southern Iowa and Missouri, for instance, the Drift is much more deeply dissected by rivers than is the case farther north, as for instance in Northern Iowa and Minnesota; showing that the rivers have had longer time to act in the south than in the north.

It seems, then, well established that the Tertiary

[1] *Physical Geography.*

epoch was followed by a spell of great cold; that during part of this period the country was (at any rate over a great part of the area) submerged to a depth of at least 500 feet; that subsequently it was raised to about the same height above the present level; that the great Scotch glacier at one period reached the coast of Yorkshire on the west, and beyond Wolverhampton on the south; and that the Scandinavian glacier extended beyond the North Sea to our East Anglian coast, covered a considerable part of East Yorkshire, and, joining with our great English glacier, formed one unbroken wall of ice. There were, moreover, perhaps other oscillations; the glaciers probably advanced and retreated several times.

The whole subject is very complicated, and requires much additional study. H. B. Woodward, who mapped part of the Norfolk district for the Geological Survey, has expressed, I believe, the general opinion of those who have worked at the subject, when he says that "after spending about a year in Norfolk I began to believe I knew all about the Drifts, but during the following seven years of my sojourn in that county, as I moved from place to place, I somehow seemed to know less and less, and I cannot say what would have been the result, but fortunately the geological survey of the county came to an end."[1]

Various reasons have been suggested to account for the low temperature of the Glacial period. Croll has suggested an astronomical cause. The form of

[1] *Proceedings Geol. Assoc.* vol. ix. 1885-86.

the earth's orbit is continually changing—though within narrow limits.

When the orbit was circular the climates of the northern and southern hemispheres would, *cæteris paribus*, be similar. If, however, the excentricity increased, the change, combined with the precession of the equinoxes, would give rise to alternate periods of 21,000 years during which, alternately, the northern hemisphere having a shorter winter became warmer, the southern having a longer winter became colder, and *vice versâ*. These considerations would account for the apparent co-existence of arctic and semi-tropical animals. I ought to add that these views, though supported by Sir R. Ball and other high authorities, are not universally adopted. Moreover, it must be remembered that the present climate is distinctly warmer than that of most countries in the same latitude.

To whatever cause the cold may have been due, the climate gradually improved, but there seems some ground for supposing that the last change has been towards a return of cold. A similar inference has been drawn from the fact that the vine appears during the Middle Ages to have been grown farther north than at present, and that certain passes in the Alps which were formerly used have now been abandoned; but both these cases are susceptible of a different explanation.

The Glacial epoch certainly contributed much to the agricultural wealth of England. It mixed together elements which would otherwise have

occupied different districts, and it covered a great part of the country with a deep and much-divided soil, admirably adapted to promote the growth of plants, and especially of trees.

In many places the higher Chalk tracts are covered by a deposit of stiff brown and reddish clay with unworn flints, sometimes as much as 20 feet in thickness. This appears to arise from gradual dissolution of the Chalk by rain. Chalk contains a minute proportion of clay, and when the Chalk is dissolved the clay remains. A curious confirmation of this view is afforded by the position of the flints. Whenever they are elongated in form they tend to stand vertically in the clay. We know that such stones in a moving mass would arrange themselves with their longer axis in the direction of movement. M'Kenny Hughes, however, has pointed out that, from the presence of whitened flints and sand, the mass must have moved "and been kneaded up by a kind of soil creep."

As the rain percolates through more easily in some places than in others, it forms hollows in the upper surface of the Chalk. Over these hollows the clay forms a sort of roof, but sooner or later it falls in, causing a depression on the surface, below which is a hollow or pipe in the Chalk filled with gravel, sand, or clay. Such pits or pipes may be seen in the face of most chalk-pits. To the untrained eye a thick layer of flints suggests sterility; but farmers know that they are a shelter against March winds, protection against summer suns, and warmth in winter frosts.[1]

[1] Dickenson, *Jour. Roy. Agric. Soc.* vol. xxii.

The latest deposits in point of time are the gravel-beds and alluvial flats in the lower reaches of so many of our rivers. These form rich land, and are usually in pasture. They are formed of the warp laid down in times of flood.

GEOLOGICAL TIME AND THE AGE OF THE GLACIAL PERIOD

The antiquity of the Glacial period measured in years must be very great, as shown, for instance, by the immense amount of denudation which has since taken place. Nearly the whole of the Fen basin has been scooped out of Boulder-clay. Deep valleys have been cut into it.

If the cold period was due to astronomical causes, as suggested on p. 79, it would indicate that the Glacial period began about 200,000 years ago, and that existing conditions commenced to return about 50,000 years ago. These dates would tally approximately with the changes which have taken place in our valleys, etc.[1]

Whether man existed in Britain before the Glacial period or during the interglacial periods of a more genial climate, there is still some difference of opinion, though it seems probable; but there can be no doubt that he was here soon after the final disappearance of glacial conditions, and coexisted with the Mammoth, the Woolly-haired Rhinoceros, the Hippopotamus, the

[1] I have gone into this interesting question at greater length in my book on *Prehistoric Times*.

Musk Sheep, the gigantic Irish Elk, the Great Bear, and the Cave Lion.

Stone implements have been found in the gravels of many of our southern river-valleys.

Some years ago Spurrell actually found near Crayford the spot where some of these ancient men had been making their implements. It was on the bank of the Thames, and had been, probably by some flood, covered over with loam, which had then accumulated to some depth without disturbing the flakes and chips. By great patience he found some that fitted, and he was even able to put them together, and thus reconstruct the original flint.

The deposits of Drift are so thick and so uneven that the inequalities have, as we shall see in a subsequent chapter, often given rise to lakes, and the deposits themselves have blocked up valleys and diverted, sometimes even reversing, the courses of rivers.

In another work[1] I have discussed the evidence on which depend our estimates of geological time, and will here only give the conclusions to which they seem to me to point.

There is still no doubt much difference of opinion; the evidence does not amount to proof, and the calculations can only be regarded as provisional estimates. Nevertheless, all the evidence of geology seems to indicate an antiquity of which we are but beginning to form a dim idea. Take, for instance, one single

[1] *Prehistoric Times.*

formation—our well-known Chalk. This consists entirely of shells and fragments of shells deposited at the bottom of an ancient sea, far away from any continent. Such a process as this must be very slow; we should certainly be well within the mark if we were to assume a rate of deposition of an inch in a century. Now the Chalk is more than seventeen hundred feet in thickness, and would have required therefore more than 2,000,000 years for its formation. The fossiliferous beds of Great Britain, as a whole, are some 200,000 feet in thickness; and many which with us measure only a few feet, on the continent expand into strata of immense depth; while others of great importance elsewhere are wholly wanting with us: for it is evident that during all the different periods in which Great Britain has been dry land, strata have been forming (as is, for example, the case now) elsewhere and not with us. Moreover, we must remember that many of the strata now existing have been formed at the expense of older ones; thus all the flint gravels in the South-East of England have been produced by the destruction of Chalk. This again is a very slow process. It has been estimated that a cliff 500 feet high will be worn away at the rate of a foot in a century. This may seem a low rate, and is no doubt in many places much exceeded; but we must bear in mind that along any line of coast there are comparatively few places which are suffering at one time, and that even there, when a fall

of cliff has taken place, the fragments serve as a protection to the coast until they have been gradually removed by the waves. It is, indeed, as yet impossible to arrive at any close or even approximate estimate, and various opinions have been expressed; but looking at the evidence as a whole, we can hardly, I think, estimate at less than 100,000,000 years the time which must have elapsed since the commencement of life on our planet.

Of this the Tertiary period might occupy say 5,000,000 years, and the Glacial period may have commenced some 200,000 years ago, coming down perhaps to within 50,000 years of the present time. Indeed glaciers may have lingered among the mountains, and occupied some of the valleys down to a much more recent period.

In any case the lapse of time which is indicated fills the mind of man with awe. But Nature has no need to consider time; has she not eternity to work in?

CHAPTER III

GENERAL CONFIGURATION

When I have seen the hungry ocean gain
Advantage on the kingdom of the shore,
And the firm soil win of the watery main,
Increasing store with loss, and loss with store ;
When I have seen such interchange of state,
Or state itself confounded to decay ;
Ruin hath taught me thus to ruminate.

SHAKESPEARE, *Sonnet* lxiv.

THE British Isles stand on a platform, the edge of which does not by any means correspond with the existing coast. The present western shore of Britain, and indeed of Europe, represents, so to say, a merely temporary and incidental condition.

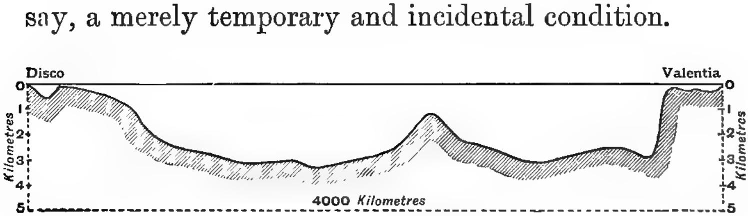


Fig. 18.—Section across the Atlantic from Disco to Valentia.

The true boundary of the continent, as Godwin-Austen pointed out long ago (1849), follows a line about 50 miles west of the Irish coast. The sea-

bottom shelves very gradually to a depth of approximately 100 fathoms, and then plunges (Fig. 18) in a steep slope, or almost a precipice, of 6000 to 8000 feet to the abysses of the ocean.

The greatest height of mountains approximates to the greatest depth of oceans, but the *average* height and depth differ remarkably.

Taking the earth as a whole, it has been calculated that the average height of continents is

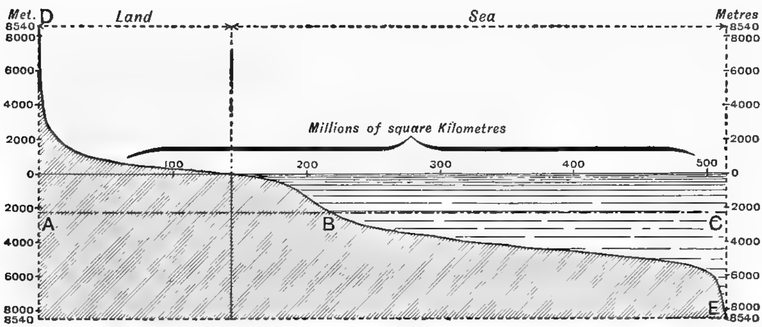


Fig. 19.—Diagram showing proportions of heights, depths, and surfaces. The line ABC separates two equal surfaces, corresponding to equal volumes, one ABD of the solid crust, the other BCE containing the abysses of the ocean.

only about 700 metres, while the average depth of the seas is about 4000 metres.

Penck has calculated, using mainly the data afforded by Sir J. Murray, that while 29% of the land surface has a height of less than 200 m. and only 2% above 4000 m., in the case of the ocean only 7% has a depth of less than 200 m., while 50% is more than 4000 m. in depth.

De Lapparent[1] has expressed this graphically

[1] *Leçons de Géog. Phys.*

(Fig. 19) by representing on a horizontal line lengths respectively proportional to the surfaces occupied by the respective zones.

If we remember that the diameter of the earth is about 12,760,000 metres, the greatest depth of the ocean 10,000 m., and the average depth 4000 m.; that the water, if spread evenly over the whole surface, would cover it to a depth of 2400 m.; that a large part of the continents have a height of only 200 m.,—we see how slight a change in conditions would be sufficient to submerge almost the whole habitable earth, and how necessary the depths of the ocean are to the very existence of the human race.

A vast area of the richest and most populated portions of the globe is indeed only 50 to 100 feet above the sea-level. In our own country it is striking to reflect that a subsidence of even less than 100 feet would submerge all the lower parts of London, Liverpool, Bristol, Newcastle, Hull, Cardiff, Southampton, Portsmouth, Chichester, etc., and would carry the sea up into the heart of the country.

The word "links," which we now associate so closely with the game of golf, originally implied only the sandy hills thrown up by the waves, and the gravelly plains left by the sea when it stood at a height relatively to the land a few feet above its present level. Chambers first called attention[1] to the terraces or flat plains which occur in so many places round our shores, and all of which he regarded as evidences of ancient sea margins.

[1] *Ancient Sea Margins.*

This comparative flatness of continents is a great advantage, for if the elevations and depressions were greater they would add much to the difficulties and expense of transport and locomotion.

Moreover, if so much of our land is but little raised above the sea, on the other hand the Irish Sea, English Channel, and the North Sea are shallow and recent depressions, and a trifling elevation of say 20 fathoms, about the height of the Monument, would join Ireland and Great Britain to France, Holland, and Denmark.

The English Channel is a valley, not only narrower but shallower towards the east; 130 feet deep at the Straits of Dover, it widens out and sinks to 500 feet towards the Atlantic. It seems probable that the anticlinal axis of the Weald formerly extended across the Channel, say from Hastings to near Cape Gris Nez, and marked the old watershed from which streams at one time ran to the Atlantic on the one side and the North Sea on the other.[1]

While, however, a comparatively slight elevation would produce so great a change in the geography and conditions of Great Britain, still, taking the world as a whole, it would have a very trifling effect. So deep are the oceans, so closely do great depths approach the coast, that, with some exceptions, a rise of even 5000 feet would along some great stretches of coast but slightly affect the contours of the continents.

On the other hand, a very slight subsidence would

[1] De Rance, *Proc. Geol. Assoc.* vol. iv. 1875.

submerge many great tracts, and destroy millions of the human race.

It is because our own present shore-line is so far removed from the edge of the continental platform, and the sea surrounding our islands is so shallow, that any alteration of level would effect a considerable change in our geography. Geology clearly proves that our islands have been over and over again under the water and out of the water, since the first appearance of life on our planet. There is also strong reason to believe, though the evidence does not amount to proof, that even since the appearance of man, and therefore in a geological sense at a very recent period, England was at a relatively lower level by several hundred feet, and the greater portion therefore was under water. Moreover, there seems no doubt that still more recently the land stood at a higher relative level, and extended to the edge of the continental plateau. Of this the Scotch sea-lochs and our river-valleys afford clear proof.

But though Great Britain may be said to be a mountain with its base in the sea, it is a mountain of a very varied and complex character. It has not been raised by one simple, simultaneous, and uniform elevation; but is the result of many varying forces, which have acted differently in different parts, and at many distant periods. The relief is again complicated by the great variety of rocks, and of the agencies to which they have been subjected—heat and cold, ice and water, wind, storms, and rain.

Few countries of so small an area offer so many

points of interest, or present such difficulties to the map-maker. We have no high mountain chains; the rivers follow complex courses (see map, p. 356), and are indeed very difficult to trace on most of our ordinary maps. We may be said to have five principal mountain groups, corresponding to five projections of the land,—the North Scottish Highlands, the South Scottish Uplands, the mountains of the Lake District, of Wales, and lastly those of Cornwall. These, however, are not mountain chains but detached mountains or groups of mountains, and the whole country is intersected by valleys affording great facilities for roads. In the Lake District Scawfell has a height of 3162 feet, Helvellyn of 3118, and Skiddaw of 3054, but between them are deep valleys.

Again, in Wales, Snowdon, Aran Mowddwy, Cader Idris, and Plynlymmon form isolated groups; while in the south-west, Exmoor and the five great Granite bosses are separated by wide valleys.

On the other hand, the hill districts are formed on quite a different plan; they do not form detached groups, but more or less continuous ridges,—the Pennines, Cotteswolds, Chilterns, and others, intersected, however, by a certain number of deep river valleys. Thus the mountains form detached groups, while the hills are ranged in continuous escarpments.[1] In the mountainous districts the strata are greatly

[1] The word "escarpment" is applied to a ridge along which a formation or bed is cut off, and beyond which it does not now extend, except in the form of outliers; it follows the line of strike. "The North Downs and the Chiltern Range are Chalk escarpments; the sharp hills along the valley of the Thames near Marlow and Maidenhead are not."—Whitaker, *Geol. of London.*

contorted and compressed; in the hilly regions they are gently inclined and little altered.

It must be borne in mind that the original surface has long since disappeared; and as the softer parts have suffered more than the harder ones, the present hills are not those which were raised the highest, but those which have undergone the least amount of denudation. The result of this is that the harder strata stand out in bosses or in escarpments. Thus an escarpment of the Carboniferous Limestone forms the Pennines (Fig. 99, p. 265), that of the Oolite the Cotteswolds, that of the Chalk the Chilterns and the North and South Downs.

The existing configuration depends on three main factors,—the original configuration, the nature of the rocks, and their inclination. The courses of our rivers have in some cases been determined by the old surface, and have no relation to the present levels. They often follow, indeed, what seem at first sight incomprehensible courses: some running inland from the sea, as for instance in Cornwall and Devonshire the Camel, Tamar, Torridge, and Exe, and several in Norfolk, Yorkshire, Wales, and elsewhere; or cutting through ranges of hills, as for instance the Dee, the Thames, the rivers of the Weald, the Humber, etc. These apparent anomalies will be dealt with in a subsequent chapter.

The northernmost of the escarpments, the Pennine range, forms part of the watershed in the North of England. This follows the escarpment of the Mountain Limestone, from Cold Fell by Cross Fell, Stainmoor,

Bow Fell, and Penyghent to near Settle; then by Todmorden, Glossop, Newcastle-under-Lyme, and Wolverhampton, along the line of the Dudley Hills, south of Birmingham and north of Coventry, to the headwaters of the (Warwick) Avon.

The strata to the North and West of England are of great age, in many cases much compressed, crumpled, and consequently hardened, so that they form high ground, and lie in more or less irregular patches on each side of the Central Pennine ridge; while those on the south-east of a line drawn approximately from near the mouth of the Tees to Exeter run in nearly parallel bands from north-east to south-west. As the traveller passes from north-west to south-east, from the valley of the lower Severn to the London basin, he continually passes from older to newer strata, from Trias over Lias, Oolite, and Chalk to the Tertiary sands, clays, and gravels.

Moreover, any one who crosses the country with a geological map in hand will observe that the aspect changes as he passes from one geological formation to another; that the present features of the country are greatly due to the character of the geological formations and the changes they have undergone.

There is a general slope of the strata from north-west to south-east, and the harder strata, such as limestone and sandstone, which are better able to resist the weather, stand out as long ridges or escarpments, while the softer ones—marls, clays, and shales—form valleys and plains.

There is no reason to suppose that the Cambrian and Silurian sandstones, slates, and limestones were originally any harder than the sands, clays, and chalk of more recent times, but they have been subjected to enormous compression; and the higher mountains of the Lake District and North Wales owe their pre-eminence not merely to the fact of their having been raised higher, but because they have suffered less from denudation. Fig. 20 gives a generalised section across Great Britain from the Menai Straits, by Snowdon, the Malvern Hills, the Oolite and Chalk escarpment, and the Tertiaries of the Thames valley, after Sir A. Ramsay.

Fig. 20.—Diagram Section from the Menai Straits across Wales, the Malvern Hills, and the escarpments of the Oolitic rocks and the Chalk.

Nos. 1 to 3 represent the disturbed Cambrian, Lower and Upper Silurian, and Old Red Sandstone mountainous country of North Wales, the adjacent country on the east, and the Malvern Hills; *g*, +, eruptive rocks; 6 to 8, the plains and slightly undulating grounds of the New Red Sandstone, Red Marl, and Lias; 9 and 10, the great Oolitic escarpment of the Cotteswold Hills, forming the first tableland; 11, the great escarpment of the Chalk, forming a second table-land, above which lie the Eocene strata 12. The Upper Oolites close below the Chalk escarpment 11 are in places of less height relatively to the sea than the edge of the Oolitic escarpment at 9.

The low lands of Cheshire and a large part of Central England consist of loose and easily disintegrated strata known as "Trias," while the centre and great part of the North of England is occupied by the Carboniferous system—the Coal-measures giving rise to the busy manufacturing districts, the Carboniferous Limestone to

the beautiful scenery of the Peak, the bleak mountains of the Pennine range and of Northumberland.

On the east the Chalk forms another tract of high land, known as the Yorkshire Wolds and the Lincoln Heights.

The Wash on the east and the Bristol Channel on the west, with the low ground reaching from each of them into the heart of the country and drained by the Avon, the Trent, the Welland, and the Nen, are mainly due to the existence of two belts of soft strata which run diagonally across the heart of England from the mouth of the Tees (across the Humber) and the Wash to the Bristol Channel and the Bay of Portland, enclosing between them a harder belt which forms the Cotteswolds.

These soft strata were long protected from the action of the sea by the belt of Chalk which runs north-eastwards from Dorchester to Flamborough Head, and is breached in two places, viz. at the Humber and the Wash.

When the gap of the Wash had been formed between Hunstanton in Norfolk and Skegness in Lincolnshire, denudation proceeded more rapidly on comparatively soft Trias, Lias, and Oxford Clay than on the harder and less destructible Limestone, Oolite, and Chalk, which consequently stand out as long ridges above the low ground of the Wash and the Midlands. Hence the valleys of the Trent, the Avon, the Welland, and the Ouse. The Ouse and its tributaries are gradually working their way back. They have already encroached on the area of the

Thames, and one branch has almost intercepted the upper Cherwell below Banbury (see map, p. 356).

Two great escarpments (see p. 218) run across the centre of England, from south-west to north-east, the northern one corresponding to the outcrop of the Oolitic strata and forming the scarp face of the Cotteswolds, the second to the outcrop of the Chalk, the summit of which is known as the Chilterns.

Many of the earlier works on Physical Geography and on the geography of former periods have been based on the supposition that the present limit of the respective strata represents the boundaries of the seas in which they were deposited. This, however, is not the case. The Chalk, for instance, at the edge of the escarpment is a deep-sea formation deposited far from land; in all probability at least 200 miles, which would carry it right across Wales. In fact the escarpment is still, though slowly, retreating, and the Chalk once extended far to the north and west, so as to join the Chalk-beds of Antrim. The Lias is now bounded by a line from the Severn to the Humber, but outliers occur near Carlisle, between Wem and Market Drayton, and again near Cardiff. Indeed, there can be no doubt that the strata generally extended to the north-west far beyond their present outcrops.

This indicates an enormous amount of denudation, and must always be borne in mind if we attempt to understand the arrangement and distribution of our mountains and rivers.

The Weald of Kent and Sussex was a dome of upheaval which extended from the north-east of

France beyond Cape Gris Nez to Rye, Petersfield, and Winchester, and which has subsequently been truncated. On each side is a depression, or syncline; that on the north forming the Kennet and Thames valley or London basin (Fig. 21), which extends from Avebury by Reading to the sea, though no doubt it has been considerably deepened by the river; while that on the south forms the Hampshire basin. The Vale of Pewsey and that of Wardour

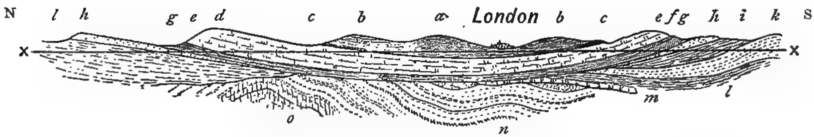


Fig. 21.—Generalised section across the London Basin, from north to south, showing the underground range of older rocks. *a*, Bagshot Sand (of Hampstead); *b*, London Clay; *c*, Lower London Tertiaries, Oldhaven and Blackheath Beds (on the south only), Woolwich and Reading Beds, Thanet Sand (on the south only); *d*, Upper Chalk; *e*, Middle and Lower Chalk; *f*, Upper Greensand; *g*, Gault; *h*, Lower Greensand; *i*, Weald Clay; *k*, Hastings Beds; *l*, Middle and Upper Jurassic Beds; *m*, Lower Jurassic Limestone with clay in the centre; *n*, Red Rocks and Devonian (possibly with Carboniferous in places); *o*, Silurian; XX, Sea-level. Vertical scale exaggerated.

are "anticlinal" valleys, that is to say, they were originally lines of elevation; but the strata, being thus stretched and loosened, have been worn away more easily than the Chalk on either side of them, and thus what was originally a hill became a valley. This explains the curious fact that the Nadder does not flow, as we might have expected, by Gillingham to the west, but by Wilton to the east and then, falling into the Avon, to the south.

This anticlinal ridge runs almost along the line of the South-Western Railway from Gillingham by

Fig. 22.—The Needles, Isle of Wight.

Tisbury to Salisbury, and almost coincides in direction with that of the Weald to the east.

South of the Hampshire basin is another great arch, the strata being at the Needles and in Scratchells Bay (Isle of Wight) even vertical (see Fig. 22), and the summit of the arch would be where the Channel now is. The existence of the central ridge of Chalk with softer strata on each side gives rise to the peculiar lozenge-like shape of the island.

In the far west, Cornwall and South Devon present us with five bosses of Granite protruded through Devonian strata, and the beautiful Serpentine rocks at the Lizard.

In the next chapter we will consider the evidence of comparatively recent changes in the relative levels of land and sea.

The irregular and complex arrangement of the land surface shows itself also in the coast-line, which manifests extraordinary diversity in character, structure, and outlines.

Every one must have observed that there is a marked difference between our east and west coasts; the west being irregular and deeply indented, the east presenting rounded sweeps. This is due partly to the greater elevation, and partly to the different hardness of the rocks, those on the west being the most ancient, and much harder, while those on our eastern shores, being more recent and more destructible, consisting of chalk, clay, sand, or gravel, have suffered far more from the action of the waves; the projecting headlands being gradually worn away, and the materials carried

into the bays. The general trend of the currents on our eastern coast being towards the south, it will be observed that the headlands tend to point in that direction, as for instance at Spurn Point, Felixstow, etc.; and the mouths of many of our eastern rivers are also deflected, some for several miles, towards the south.

A glance at the map of Europe will show that there is a remarkable difference between the rivers of the Atlantic and those of the Mediterranean. The Atlantic rivers terminate in estuaries, those of the Mediterranean in deltas. Our rivers terminate in estuaries because the land stood at a recent period (speaking of course geologically) at a higher level than the present; but these estuaries would have been to a great extent filled up ere now if it had not been for the action of the tides. The Mediterranean, on the contrary, is almost tideless, and the rivers have been able to build out deltas.

The cliffs, which surround so great an extent of the island, show how greatly the shore has been cut back by the waves. In parts, however, as for instance the Fens, Romney Marsh, etc., there are considerable areas which have been reclaimed from the sea, and are but little above the sea-level. They resemble Holland more than the rest of England.

If a mountain which has been much denuded, and in which the rivers have cut deep valleys, is lowered so that the upper part only remains above the sea-level, the district assumes more or less the shape of a hand, with long promontories or islands, such as

those for instance of the Morea. This also accounts for the remarkable form of the island of Celebes and its miniature Gilolo.

Hence the deep fjords on the west coast of Scotland and of Norway. They are drowned river-valleys, (whence the windings they sometimes exhibit) and the islands are culminating points of the ancient ridges which once separated the valleys from one another. On the other hand, such coasts as those of Africa or Central America are unindented, because they follow closely the real continental boundary, and sink therefore rapidly to profound depths.

The most remarkable geographical feature of North Britain is the Great Glen,[1] that deep valley in which the Caledonian Canal has been made, and which, commencing in the south-west with the Firth of Lorne and continued through Loch Linnhe, Loch Eil, Loch Lochy, Loch Ness, and the Moray Firth, divides Scotland in two.[2] The east coast of Sutherland and Caithness follows nearly the same direction, and if we continue it still farther north we come to the coast of Norway. This depression is, moreover, only one of many lines following the same direction. Beginning with the north-west, we have the outer coast of the Hebrides, the Minch, Sleat Sound, the valley of the Findhorn, the Sound of Jura, Loch Awe, Loch Ericht, and the River Spey, Loch Fyne and Loch Tay, the Solway Firth, etc.

It will also be observed that there are a number of

[1] See Lubbock, *Geogr. Journ.* vol. vi. 1895.

[2] This is a very ancient line of disturbance—more ancient even than the Old Red Sandstone times.

other lines running at right angles to the first set—namely from north-west to south-east. These also are best marked in Scotland. In Sutherlandshire we have Loch Shin and Loch More, and coming southwards the two Loch Brooms, Loch Ewe, and Loch Maree, the Sound of Harris and a number of channels running across the main line of the Hebrides, Loch Torridon, Loch Duich, Loch Hourn, Cuillin Sound, the Sound of Mull, the North Channel, Loch Lomond, Loch Ryan and Luce Bay, Wigtown Bay, and the valleys of the Nith, Clyde, Teith, Tay near Dunkeld, etc. The predominant effect of these two lines on the geography of our country has not hitherto, I think, received the attention it deserves.

Though most strongly marked in Scotland, these two main lines are well seen in England also: for the north-east and south-west lines we have the Menai Straits and north coast of Carnarvon, the north coast of Cardigan and Pembroke, the line of the Bristol Channel from Gloucester to Cape Cornwall, and some of the principal hill ranges, the Cheviots, the Cotteswolds, the Chilterns, etc.; while for the transverse lines I might mention the Weaver and lower Mersey, the lower Dee, the Clwyd, farther south the upper Severn, the Wye, the western Colne, and several other Thames tributaries, Southampton Water, etc.

The tendency of earth movements to follow these two directions is by no means confined to the surface, but continues far down into the depths of the earth. The strata on the two sides of the Caledonian Canal are coloured alike on geological maps, and quite

correctly, for both are Gneiss, but they are of different ages. Other lines of disturbance follow the same direction, as for instance the two great parallel faults which cross the South of Scotland from sea to sea; the fault from near Greenock to Stonehaven, and that from Loch Ryan to Dunbar, etc. In England, as already mentioned, the general strike of the strata is from south-west to north-east, and the great lines of fracture tend to this direction, or one at right angles to it. There are also two other series, one north and south, the other east and west, which do not appear to go so far back in time.

The intersections of the two main lines also explain certain features in our river courses which would otherwise be inexplicable. Where the surface of the country is flat or presents an uniform slope, rivers run in curves, the diameters of which depend mainly on the quantity of water and the inclination of the ground.

In many cases, however, we find that rivers suddenly turn at, or nearly at, a right angle. Small maps do not show this so well as they should, for map-makers like to represent rivers with sweeping curves. The great angle of the Rhone at Martigny is a typical instance, but we have many cases in our own country—the Tummel near Pitlochry; the Tay at the junction with the Isla, and again where it enters the Firth of Tay; the Clyde at Carmichael, and again at Gourock; the north Tyne, Tees, Hodder, Calder, and Ribble, Irwell, Derwent, Soar, and Trent, the upper Severn, the Thames above Oxford, at Reading, and

again where it is joined by the Wey, etc. In fact, the Thames near Oxford really falls into the Cherwell and at Reading into the Kennet.

This characteristic of many river courses has long been noticed.

"Why," asked Phillips,[1] "should the Tees be deflected first into the path of the smaller river Greta, and afterwards into that of the still smaller stream from Staindrop?"—but so far as I am aware no answer has been attempted. It is to be explained, I believe, by the two systems of intersecting lines already referred to.

In the chapter on Mountains I will endeavour to explain the causes which seem to me to have given rise to these two great directing lines, and I merely refer to them here as interesting and important facts bearing on the configuration of our island.

The general strike or outcrop of the strata is, as already mentioned, south-west to north-east, and the folds at right angles have split, so to say, the outcrop of some of the formations into two distinct arms, one following the general direction, the other making an angle with it. Thus the Chalk to the south of the Tertiary strata forming the London basin is brought up to the surface by the ridge of the Weald, and is divided into two long arms running north and south of the Weald of Kent, joining the main outcrop in North Hampshire and Wiltshire, thus making a broad central expanse of Chalk, the nucleus of which is known as Salisbury Plain.

[1] *Geol. of Yorkshire*, part ii.

Another great anticline is that of the Pennines, which similarly splits the Triassic rocks into two arms, one following the normal direction to the north-east, while the other runs to the north-west through Cheshire and Lancashire to the Solway. The junction is near the centre of England, where the wide expanse of Trias gives its character to the rich scenery of the Midlands.

While considering the causes which have determined the configuration of a country, we must bear in mind the great changes in climate. We know that our own country was once subjected to an Arctic climate, and to a great extent covered by a sheet of ice; and that elsewhere districts now well watered and fertile were once dry and desert; while others now dry and desert were once rich and populous.

The changes of elevation have been as important as those of climate. Of this our river-valleys afford clear proof.

It is evident that no river can excavate its valley below the sea-level. As the stream approaches the sea, or rather the sea-level, the current is checked, its power of erosion diminishes, and it commences to deposit. Perhaps it will be said that the present valleys do not descend below the sea-level, and in one sense this is true. Just, however, as the present shores do not represent the true boundaries of the continents, so the levels of the present rivers do not give us the true depth of the valleys, which in many cases descend much below the present surface, and are filled up by a greater or less

thickness of gravel and other river deposits. It is the base of these deposits which gives the true depth of the valley.

We may indeed lay it down as a general proposition that our river-valleys descend below the sea-level.

Our estuaries are, in fact, drowned river-valleys. As a general rule they go down at least 100 feet, and in some cases much more, below high-water level. In the Thames and Humber the depth is over 100 feet, that of the Tees 200, of the Mersey 200, of the Dee 280, and near Furness 480.

At Boston a deep valley has been excavated to a depth of 500 feet below the sea-level,[1] and this is almost filled by Boulder-clay. The sea could not have cut such a valley, nor could a river have done so unless the land was higher, to at least that extent, than it is at present. Godwin-Austen, moreover, long ago pointed out that the valleys of many of our rivers are carried out to sea.

The Admiralty charts show that from the mouth of the Wash a channel, shown by the ten-fathom line, runs out to sea for 24 miles. Similar conditions occur in other countries. In the case of the Seine it is still possible to trace below the sea the ancient meanders of the river.[2] The course of the Adour, of the Hudson,[3] of the Zambesi,[4] and other great rivers have been traced far out to sea.

This subject has been worked out with much ability by Professor Hull, who, however, perhaps

[1] Miller and Skertchly, *Fenland.*

De Lapparent, *Leç. de Géog. Phys.*

[3] Dana, *Geology.*

[4] Buchanan, *Scot. Geog. Mag.* vol. iii. 18 :7.

carries the argument farther than the facts entirely warrant. Some of the deep channels to which he refers are, moreover, unconnected, I think, with present rivers, and may go back even to Secondary times.

Another proof that the land once stood relatively higher is afforded by the numerous instances of peat or forest ground at or below the present sea-level. They were observed long ago: that of St. Brides Bay, near St. Davids, by Giraldus Cambrensis 700 years ago; that of Mounts Bay by Leland; that near the Lands End by Borlase in 1758; and several were described by Smith of Jordan Hill.[1] Such beds, indeed, occur at intervals all round our low coasts, and at the mouths of almost all our larger rivers. We cannot suppose that these forests grew at the very edge of the water. At present there are not along our whole southern coast any woodlands immediately adjoining the sea, nor even many single trees of any magnitude. Moreover, the species—Ash, Wych-elm, Scotch Pine, etc.—are trees which do not well support the sea air. Remains of Elephants, Rhinoceroses, etc., have been found in the submerged forest-beds.

Fig. 23 represents one of these forest-beds on Leasowe shore, Cheshire. The level is about 6 feet below high-water mark. The trees are of existing species, and range up to 18 inches in diameter. The bed is gradually disappearing under the action of the waves, and will not survive many more years.

Among the localities where submerged forests occur

[1] *Quart. Jour. Geol. Soc.* vol. iii. 1847.

round our coast may be mentioned Cardurnoch on the Solway, Holyhead in Llandrillo Bay, Cardigan Bay, St. Brides Bay, and Swansea Bay; at Holly Hazle near Sharpness; at Stolford near the mouth of the Parret; in Cornwall at Looe, Fowey, Mounts Bay, etc.; at many places along the coast of Devon—at

Fig. 23.—Forest-bed, Leasowe shore, Cheshire.

Braunton Burrows in Barnstaple Bay, in Torbay, Blackpool, North and South Sands in the Salcombe Estuary, in Bigbury Bay, near Sidmouth, and many other places along our southern and eastern coasts.

These lines of evidence point to a time when the land stood at a relatively higher level than at present, and a difference of even 200 feet would turn a great part of both the English Channel

and the North Sea into dry land. We must therefore picture to ourselves a former state of things, when England formed part of the continent of Europe; when our southern rivers, with those of Northern France, ran down the great valley now forming the English Channel, and opened into the Atlantic Ocean; when the North Sea was a great plain, and the Thames, after joining the Rhine and subsequently the Humber, ran northwards into the Arctic Ocean. It was along the banks of this great river, and over the surrounding plains, that the Bears and Lions, Bisons and Elks, Rhinoceroses, Hippopotamuses, and Elephants lived whose remains are so abundant on the bed of the North Sea, as well as in many of our river-valleys.

The final sinking of the North Sea is so comparatively recent an event that it may even have occurred since the advent of man.

The English Channel was probably once a river-valley, which subsequently sank below the sea-level, and has since been widened by the action of the waves. If we carry our imagination back to the period of extreme cold, when the Scandinavian glacier stretched across the North Sea and reached our shores from Norfolk northwards, it is evident that the waters of the Rhine would have been blocked, and it seems probable that they formed a great lake with its overflow through the Straits of Dover, and so down the English Channel, receiving the Thames, the Seine and Solent, the river of the Irish Sea, and many minor streams; formed rapids or waterfalls at the

Race of Portland and the Channel Islands, and finally fell into the Atlantic.

With the disappearance of the ice the Rhine resumed its old course, being joined by the Thames and the Humber, and eventually falling into the Arctic Ocean, until another subsidence formed the North Sea, and gave our islands approximately their present outline.

RAISED BEACHES

The last change of level appears to have been a slight elevation, as shown by the presence of sea-

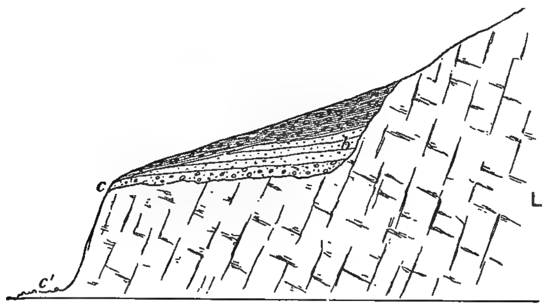


Fig. 24.—Raised Beach at Weston-super-Mare. L, Carboniferous Limestone; *b*, sand concreted below; *c*, raised; *c'*, present beach; *a*, talus.

beaches, rising in some places to 150 feet above the present water-level.

It is not of course every deposit containing sea-shells at a level above high-water which is a raised beach. The waves often throw shells and shingle several feet above the highest tide.

True raised beaches were noticed by Borlase as long

ago as 1758, and occur at intervals all round our coast. The town of Spittal in Northumberland stands on one,[1] which, however, is much obscured in places by heaps of blown sand. Along the greater part of the east coast the wear and tear have been so great that we could not expect to find any remaining. Along the south and west coasts, however,[2] it has in places only

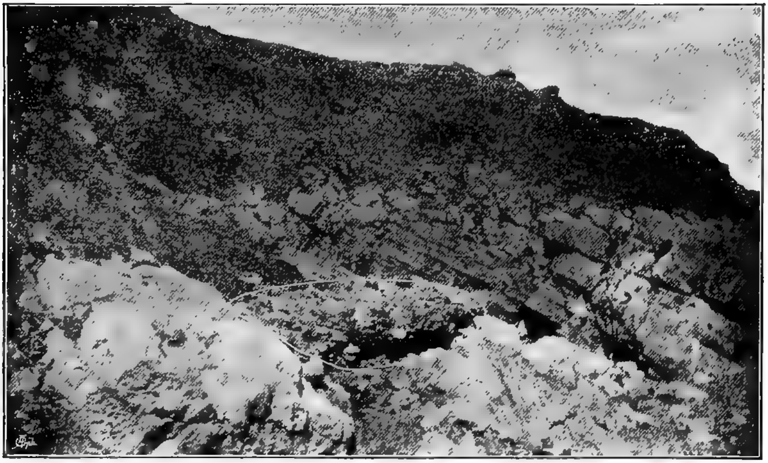


Fig. 25.—Piece of Raised Beach at the Mumbles, near Swansea.

brought the coast back to the old line; and raised beaches occur at Brighton, in the Isle of Wight, at Portsdown Hill, on Portland Bill, at various places along the coasts of Devon and Cornwall, especially at Hopes Nose near Torquay, and on the Thatcher rock, at the west end of the Hoe (Plymouth), at Marazion Bay, the Lands End, St. Ives, Fistral Bay near New

[1] *Mem. Geol. Surv.*, Berwick-on-Tweed.

[2] See Prestwich, *Quar. Journ. Geol. Soc.* vol. xlviii. 1892. A convenient summary has also been given by Mr. Ussher, *Geol. Mag.* vol. vi. 1879.

Quay, Barnstaple Bay, Weston-super-Mare (Fig. 24), along the Gower Coast (where there is a remarkable series of caves rich in Mammalian remains), at Rhos Sili, the Mumbles (Fig. 25), and other places. Tiddeman has satisfied himself that in South Wales these raised beaches are older than the Glacial Drift.

Robert Chambers was the first to call attention to the many ancient terraces still existing round our coasts, and I have thought it would be interesting to give here one of the illustrations contained in his classical work on *Ancient Sea Margins* (Fig. 26).

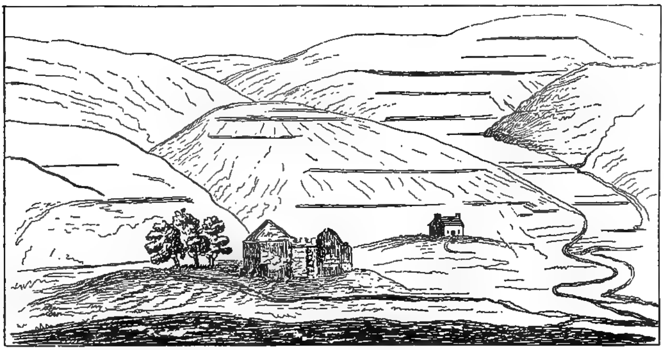


Fig. 26.—Marine Terraces at Crawford, Lanarkshire.

The "carses" of the Clyde are raised sea-margins: the 25-foot terrace is especially important—Dundee, Greenock, Ayr, and several other Scotch towns being wholly or partly built on it.

Nearly 100 species of Mollusca have been found in the raised beaches, and they indicate a northern, but not an Arctic, climate.

The Gower caves contained remains of *Elephas*

primigenius (the Mammoth) and *E. antiquus*, two Rhinoceroses (*Rhinoceros antiquitatis* and *R. leptorhinus*), the Hippopotamus, Reindeer, Irish Elk, Bison, Hyena, Cave Lion, Cave Bear, and many of our existing species.

The raised beaches vary from a height of 10 to 150 feet above the present sea-level. The one at Brighton is only 12 feet above the high-water level, at Arundel it is 100, and at Bourne Common, 42 miles distant, it has risen to 142 feet, showing considerable differences of elevation.[1]

Even this change, however, though recent geologically, was probably long ago if measured in years, and we have no clear evidence of change in historical times.

Smith of Jordan Hill appears to have established satisfactorily that the Roman Vallum at its terminations on the Firths of Forth and of Clyde was built with reference to the present relative level of sea and land.[2]

Dr. Bruce, in his history of the Roman Wall, remarks that the Romans probably ended the Wall at Bowness, because while the Solway east of Bowness has always been much used as a ford at low-water, no passage across it west of Bowness has ever been made. But it is evident that an addition to the average depth of the water east of Bowness of even 5 or 6 feet would have destroyed the practice of fording there, and the Romans would probably have ended the Wall opposite Rockcliff.

[1] Prestwich, *Quar. Journ. Geol. Soc.* vol. xlviii. 1892.
[2] Chambers, *Ancient Sea Margins.*

On the other hand, greater elevation in Roman times to the amount of 5 or 6 feet would probably have resulted in an extension of the Wall westward of Bowness, or in the building of a camp somewhere between Bowness and Beckfoot, of which there is no trace. These considerations seem to show that here, at any rate, there has been no appreciable change of level for 2000 years.

There is, as I have already mentioned, some reason to suppose that at an earlier, but still comparatively recent period, England stood at a relatively lower level, and that a great part of the country was under water. Moreover, as we see round our coast such stupendous evidence of the power of the waves and wind, and as many of our valleys are occupied but by small streams, which in many places tend to fill up rather than to excavate their valleys, it was natural that the earlier observers should attribute the general configuration of the surface to marine rather than to aerial action. Thus Sir A. Ramsay[1] himself, who afterwards did so much to prove the immense influence of rivers and glaciers, was at first inclined to attribute the modelling of the land surface, and even the great escarpments, almost entirely to marine action.

Mackintosh, in his interesting work,[2] assumes throughout that the modelling of the surface of our islands has been effected by the sea; and it is because it has, I think, been clearly proved that it is mainly

[1] *Mem. Geol. Sur.* vol. i.
[2] *Scenery of England and Wales.*

due to rain and rivers that I differ from him so much as to the interpretation of the facts.

The valleys are not mainly due to the sea, and the plains are not generally marine, but river, plains. There are indeed various kinds of plains or terraces, to which I shall have to refer again in the chapters on the Coast, on Volcanoes, on Rivers, and on Lakes.

We may divide plains into two principal categories,—plains of abrasion and plains of deposition.

Some, again, are of *aerial*, some of *marine*, some of *river*, and some of *lake* origin. *Marine plains* are in some cases due to denudation, and consist of the preexisting rock, cut down to a level (Fig. 31, p. 127). In others, and especially at the heads of bays and mouths of rivers, they are built up and formed of materials brought by water. In some cases these two causes may be combined, the projections of rock being planed off and the hollows filled up by the waves. The depth to which the process reaches depends upon the currents and the waves; and hence, though the time required would be longer in the case of hard rock, the ultimate depth does not depend upon the nature of the bottom.

Volcanic plateaux are due to sheets of lava, or of sill, which have been subsequently denuded.

Rivers tend to form plains partly by denudation, and partly by the deposit of silt, gravel, etc. Such plains have a fall in the direction of the sea, but it is often so slight as to be almost imperceptible.

Lake-plains are gradually formed by the slow deposit of fine material and the growth of plants. The bottoms of many of the Cumberland and West-

moreland lakes are level plains, and the bottom of Wast Water is said to be the flattest piece of ground in the British Isles.

The final result of aerial action would, indeed, be to reduce any country to a plain with a gentle inclination to the sea. Before, however, this ultimate result is attained, earth movements generally recommence, and fresh inequalities are produced. This alone has rendered possible the existence of man upon our globe. If the crust of the earth had been strong enough to have supported itself as a continuous arch, and the surface had retained the form of a regular spheroid, it would have been covered by a continuous sheet of water, some thousands of feet in depth. It has been the folding and fracturing, and the consequent sinking of the surface in places, which has given rise to the abysses in which the waters have collected, thus forming oceans of enormous depth, and allowing the continents to emerge.

Thus then the causes which have led to the present configuration of the land are very varied, and even surfaces apparently similar may have entirely different origins. Our island has undergone change after change; elevation and depression, deposit and denudation, have succeeded one another over and over again. Some of these changes are clearly written in the geological history; there are some to which perhaps the clue is lost for ever, but the discoveries already made justify the hope that many problems which are still obscure will eventually be explained.

CHAPTER IV

THE COAST

Roll on, thou deep and dark blue Ocean—roll!
Ten thousand fleets sweep over thee in vain;
Man marks the earth with ruin—his control
Stops with the shore;—upon the watery plain
The wrecks are all thy deed, nor doth remain
A shadow of man's ravage, save his own.

. . . .

Thy shores are empires, changed in all save thee—
Assyria, Greece, Rome, Carthage, what are they?
Thy waters wash'd them power while they were free,
And many a tyrant since; their shores obey
The stranger, slave, or savage; their decay
Has dried up realms to deserts: not so thou—
Unchangeable, save to thy wild waves' play;
Time writes no wrinkle on thine azure brow:
Such as creation's dawn beheld, thou rollest now.

Childe Harold, iv. 179-182.

THE shores of England present a series of pictures of great beauty and variety. The Chalk cliffs, which are generally regarded as so typically English, and are said to have given our island one of its names, occupy but a small part of the English coast, namely from Filey to Spurn Head in Yorkshire, part of North

Norfolk, the Isle of Thanet, Kent from Deal to Folkestone, part of Sussex, of the south shore of the Isle of Wight, and of Purbeck. These cliffs are strikingly white, though there is some red Chalk at Hunstanton in North Norfolk. Elsewhere we have grey cliffs, as in the Mountain Limestone of Northumberland and South Wales, the Cambrian of Cardigan Bay; the sombre hue of the Coal-measures and Kimmeridge Clay; the red of the Old Red Sandstone; the variegated clays, gravels, and sands of East Anglia and Hampshire; the granite cliffs of Cornwall; and last, but not least beautiful, the mottled red and green serpentine of the Lizard.

The strata are horizontal in some places; at others inclined at various angles towards, or away from, the sea; some even perpendicular, as at the Needles (Fig. 22, p. 98), the Cove of Lydstep (Fig. 42, p. 145), etc.

The west coast is most indented, especially in the north; the land is higher and the rocks harder.

Moreover, apart from the geological differences, which are greater than in almost any equal length of coast in any part of the world, there are endless diversities in the character of shore—steep and lofty precipices, as for instance in Cornwall (Fig. 27) and Wales and the Chalk cliffs of Kent and Sussex; low hills, as in East Anglia; gravel beaches, such as the celebrated Chesil Bank, Dungeness, and Orfordness; expanses of sand, as at Morecambe Bay and the mouth of the Ribble; bold promontories, as the Lleyn, the Lands End, and the Lizard; deep bays, such as those of Cardigan, St. Brides, or the Wash; and estuaries,

Fig. 27.—Granite Coast, Cornwall.

such as the Bristol Channel, the mouth of the Thames, and the Humber. No map, not even a geological map, can give any idea of these endless varieties. Strata of the same geological age may be composed of sand, clay, limestone, or volcanic rock; it may, and often does, vary in colour; it may be hard or soft, unaltered, metamorphosed, or cleaved; it may stand at any inclination; it may be rugged or ground to a flat surface by glaciers; may be dry and waterless, or deeply intersected by streams.

On the map projections of the land may look alike, but yet belong to perfectly distinct categories; for instance—

Cliffs or Headlands,
Forelands, and
Deltas.

Cliffs, where the sea has eaten back into the land, wearing away the rock and forming a more or less steep face, with a plateau shelving out to sea, as at Flamborough Head, Beachy Head, or the Lizard.

Forelands, where masses of sand and shingle have been built out by the waves, and have a steep inclination to the sea with deep water close inland, such as Spurn Point, or Dungeness.

Deltas, which are built out by rivers, and shelve very gently with shallow water for some distance, such as those of the Rhone, the Po, or the Mississippi.

On the map, for instance, the three projections of the land, Selsey Bill, Beachy Head, and Dungeness, look very much alike. In reality, however, they are entirely different: Beachy Head is a fine chalk cliff,

cut back by the sea, and with deep water near the land; Dungeness consists of gravel banks built out by currents so that they have reached deep water, and even large vessels can come close to the shore; while Selsey Bill is composed of Tertiary deposits, and the sea is quite shallow for some distance from land.

The character of the shore will also be influenced by the configuration of the land-surface, that of the sea-bottom, the winds, tides, currents; while, last but not least, the length of time during which the present condition of things has existed must be taken into consideration. Again, a coast on which the last movement has been a rise of the land relatively to the sea will present a marked contrast to one along which the land has sunk relatively to the sea.

The coast, like the land surface, has undergone much erosion, but it is of a different character: that of the coast is horizontal, of the land-surface vertical: on land the harder strata project upwards, along the coast-line outwards.

Not only every headland and bay, but even the minor features of the coast, are due to natural causes, though we may not always know how they have been produced. Lulworth Cove (Figs. 28, 29), for instance, is not only very beautiful but very interesting. The strata are highly inclined, and the Purbeck and Portland Beds are hard, but fractured at intervals, and the sea has forced its way through them in several places. Behind them are the softer sands and mud-banks of the upper Purbeck and Wealden, backed again by the harder strata of the

Fig. 28.—Stair Hole and Lulworth Cove.

Chalk. As soon as the waves broke through the hard barrier, they began to wear away the softer beds and carry the debris out to sea. This stage is shown by Stair Hole (Fig. 28). The bay became larger and larger, and widened first to a circle, as in Lulworth Cove (Figs. 28 and 29), which has a width of about 450 yards, and then to a long oval, as is shown in Worbarrow Bay.[1]

These differences are some of those which have produced the endless variety of our sea-shores, and the subject would require a volume, or rather a series of volumes, to itself. Nevertheless there are some general remarks which may be made, and some cases which are of frequent occurrence.

The relative age of a coast-land is to some extent indicated by the height of cliffs, the dimensions of the deltas formed by the rivers, and of bars of sand and shingle built up by the waves.

Such deductions, however, though generally trustworthy, are not without exceptions. For instance, if a rocky and uneven sea-bottom is uplifted, the new coast-line will be rugged and indented; while, on the other hand, if a sinking coast consists of soft and loose strata, the inequalities will tend to disappear. The contrast between the east and west coasts of England is not so much due to differences of subsidence or elevation, as to the relative hardness of the rocks on the west.

The sea-lochs of Scotland, the fjords of Norway, and deep indentations of our English coast such as the mouths of the Lune, Ribble, Mersey, Dee, Milford

[1] *Mem. Geol. Surv.*, Isle of Purbeck and Weymouth.

Fig. 29.—Lulworth Cove.

Haven, Truro river, Plymouth Sound, Southampton Water, etc., are really drowned river-valleys, excavated at a time when the land stood higher relatively to the sea-level than it does at present.

As a rule, when the land is sinking the water is relatively deep, and the drowned river-valleys make the coast irregular and complicated; while, on the contrary, when the land is rising the water is shallow, the shore shelving and simple, because the form of the sea-bottom is smoother, and with fewer inequalities than that of the land. On land the action of rain and rivers gives rise to the formation of valleys, thus producing inequalities on the surface; and though these would eventually be reduced and the final result would be a great river-plain, yet but a small proportion of the land has arrived at this final condition. On the other hand, under water the circumstances are different, and round our coasts the materials derived from the shore are strewn over the bottom, tending to fill up any inequalities; though currents cause hollows in certain places, especially where the tides are strong.

When we think of the sea-shore three images rise to the mind—the Cliff, the Shingle, and the Sands.

THE CLIFF

When the sea is attacking the land, as along a great part of our shores, the waves give rise to a platform or shelf terminating in a cliff.

If the tides alone acted on the shore, the outer or

lower edge of the platform would correspond approximately to the low-water, and the inner or upper line to the level of the waves at the highest tides; but to these limits some allowances must be made for the height to which waves rise in storms, and the depth to which they act below the surface.[1]

The planing action of the sea does not, indeed, range much below low-water mark.[2] As far, however,

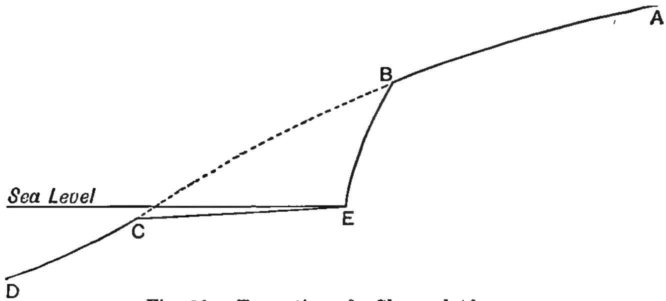


Fig. 30.—Formation of a Shore-platform.

as the action of the waves extends, if ABCD (Fig. 30) be the original slope of the land, the sea will gradually cut the land back to the line ABECD, and thus make a plain of marine denudation.

The magnificent cliffs of the wild and picturesque South Devon coast are in many cases unapproachable except in a boat, and then only in the calmest weather. Bonney, speaking of the grand headland of Start Point, says that "rarely, except in the recesses of the Alps, have I found a spot so perfect in its solitude or so impressive in its grandeur."[3]

[1] The upper limit of the olive-green seaweeds (*Fucus*) may be taken as about the mean sea-level.

[2] Godwin-Austen, "The English Channel," *Quar. Jour. Geol. Soc.* vol. vi. 1851.

[3] *Quar. Jour. Geol. Soc.* vol. xl. 1884.

Fig. 31.—Widemouth Bay, Bude.

Fig. 31 represents such a shore-platform and low cliff at Widemouth Bay, near Bude.

Another sea-plateau, also left dry at low-water, connects St. Michael's Mount, near Penzance, with the mainland (Fig. 32).

In Fig. 42 (p. 145), also, the summit of the Carboniferous Limestone, which looks almost as flat as if done with a ruler, is probably an ancient plain of marine denudation.

It follows from these considerations that if we imagine any small island acted upon by the sea, the result would be that the land would be cut back and the island would be surrounded by a platform, which would gradually widen at the expense of the island, until the land at length disappeared and was represented by a flat-topped reef. The Channel Islands are going through this process. They stand on a submarine plateau; some are reduced to rocks, such, for instance, as the Caskets, and some have been quite planed away. The Pomier, for instance, is a rocky plateau rising from a depth of 170 feet to within 36 feet of the surface. The Little Sole Bank rises from deep water, more steeply and to a greater height than that of Snowdon above the sea-level, and forms a platform at a depth of 50 to 60 fathoms.

If any part of a coast-line is less firm and well protected than the rest, the waves at once find it out and make a breach or cavern in it, which they then continually enlarge. Fig. 33 shows a natural arch in the coast near Torquay, and it will be seen that this

Fig. 32.—St. Michael's Mount, near Penzance.

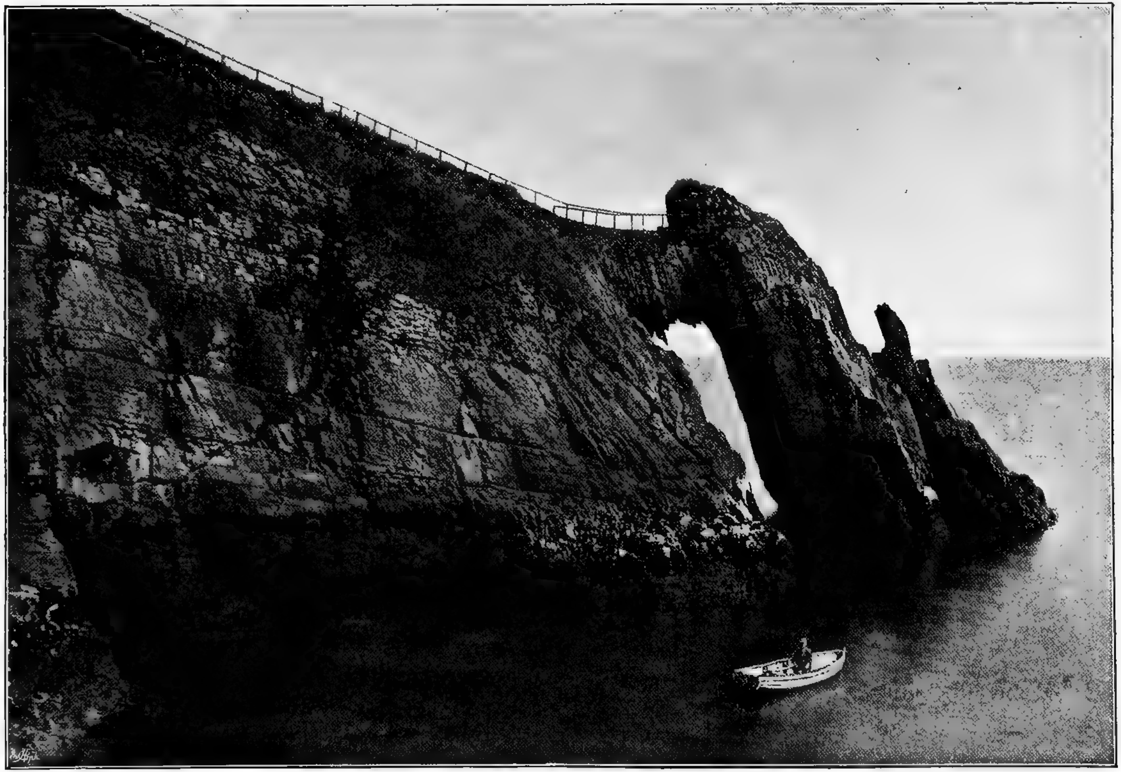


Fig. 33.—Natural Arch near Torquay.

is due to certain lines of weakness between two more solid portions of the rock. The sea has worn this away more rapidly than the rest, forming a passage below covered by a natural roof.

The waves act more effectively on horizontal strata than on those which are inclined inwards, while those which slope down towards the sea offer the most effective resistance, unless indeed they contain beds of clay, when land-springs often give rise to slips.

The inequalities in hardness, and the cross fractures, often result in projecting stacks being separated from the rest of the rock, and left standing separately, as the Needles of the Isle of Wight (Fig. 22, p. 98), or the "Stack" Rocks, one of which, at Pen-y-holt, near Tenby, is shown in Fig. 34. The celebrated Stack known as the Old Man of Hoy is 600 feet in height.

The cliff once formed is attacked by wind, rain, and frost. The water which percolates from the surface is also a potent engine of destruction, especially in soft strata, like those of Norfolk, or where they are much fractured.

The aspect of a sea-coast in fine weather gives no adequate conception, or rather gives a most misleading idea, of the power of the sea. During storms the waves afford indeed a majestic spectacle, as they dash themselves against the shore. Several times a minute they charge the coast, and break into foam and spray.

Mr. Scott Russell calculated that a roller of the ground-swell 20 feet high has a pressure of about

Fig. 34.—Stack Rock, Pen-y-holt, near Tenby.

a ton on every square foot. In Stevenson's experiments the average force of the Atlantic in winter was found to be over 2000 lbs. per square foot; in summer about one-third of that amount. The pressure of the winter breakers at Dunbar was found to mount up to 3½ tons per square foot.

At Plymouth during the severe gales of 1824 and 1829 masses of limestone from 2 to 5 tons in weight were rolled about on the breakwater like pebbles; and a piece of masonry weighing 7 tons was washed back 10 feet, though it formed a part of the pier in Bovey Sand Bay, and stood 16 feet above an 18-feet spring-tide.[1]

To many persons the following description by Ruskin will give even a more vivid idea :—

"Few people, comparatively, have ever seen the effects on the sea of a powerful gale continued without intermission for three or four days and nights; and to those who have not, I believe it must be unimaginable, not from the mere force or size of surge, but from the complete annihilation of the limit between sea and air. The water, from its prolonged agitation, is beaten, not into mere creaming foam, but into masses of accumulated yeast, which hang in ropes and wreaths from wave to wave, and, where one curls over to break, form a festoon like a drapery from its edge; these are taken up by the wind, not in dissipating dust, but bodily, in writhing, hanging, coiling masses, which make the air white and thick as with snow, only the flakes are a foot or two long

[1] De la Beche, *Researches in Geology*.

each; the surges themselves are full of foam in their very bodies, underneath, making them white all through, as the water is under a great cataract; and their masses, being thus half water and half air, are torn to pieces by the wind whenever they rise, and carried away in roaring smoke, which chokes and strangles like actual water.

"Add to this, that when the air has been exhausted of its moisture by long rain, the spray of the sea is caught by it, as described above, and covers its surface not merely with the smoke of finely-divided water, but with boiling mist; imagine also the low rain-clouds brought down to the very level of the sea, as I have often seen them, whirling and flying in rags and fragments from wave to wave; and finally, conceive the surges themselves in their utmost pitch of power, velocity, vastness, and madness, lifting themselves in precipices and peaks furrowed with their whirl of ascent, through all this chaos; and you will understand that there is indeed no distinction left between the sea and air; that no object, nor horizon, nor any land-mark or natural evidence of position is left; that the heaven is all spray, and the ocean all cloud, and that you can see no farther in any direction than you could see through a cataract."

Nevertheless it may be doubted whether waves of clear water have much power over hard, compact rock. Of course, when the cliffs consist of clay or gravel, or where the rock is disintegrated by fractures, the case is different. In many cases, moreover, the wear and tear which are attributed to the sea are

greatly due to land-springs, and the sea does little more than move away the fallen masses. Landslips also exercise a considerable influence. Shingle and rock fragments, moreover, are generally present, and in high winds the waves hurl them against the shore.

Sir. A. Geikie tells us that during north-westerly gales the windows of the Dunnet Head lighthouse, at a height of upwards of 300 feet above high-water mark, are said to be sometimes broken by stones swept up the cliffs by the sheets of sea-water which then deluge the building.

The effects of waves and storm are so impressive, and appeal so forcibly to the imagination, that we are apt to attribute the loss of land mainly to this cause. As a fact, however, denudation is even more effectively carried on by the almost insensible action of subaerial causes. Cliffs are nearly, sometimes they are quite, vertical. But they rarely overhang; in fact they generally project at the base by a succession of small steps. It is clear, therefore, that the upper part is receding at least as quickly as the base. Indeed, there are few places either on our own side of the Channel, or on that of France, where the sea at high-water regularly reaches the base of the cliff. As a rule this only happens at spring-tides. What really happens is that the action of the weather continually detaches masses of rocks, which fall on the shore, and are gradually removed by the waves. Sir J. Prestwich was of opinion that the beaches along our south coast did not derive much of their shingle direct from the chalk cliffs, but that most of it came from the gravel

of the river-valleys.[1] The sea can only act along the coast-line; rain is ubiquitous.

Sea erosion is horizontal and leaves headlands; rain erosion is vertical and leaves hills; along the coast the harder rocks stand out, inland they stand up.

Sir A. Geikie has pointed out that if we suppose the sea to eat away the coast at the rate of 10 feet a century, which is certainly above the average, to demolish 10 miles would require 528,000 years, and it would take 5,280,000 to eat away each 100 miles. But if we take the rate at which the whole surface is worn down at about a foot in 3000 years, Europe would be almost entirely worn away by rain and rivers in about 5,000,000 years, during which time the sea could only strip away a fringe some 80 to 100 miles in width. These figures are, of course, in any case only approximate, and as a rule the sea, after a certain amount of erosion, dams itself out by building up sand-dunes.

If in Fig. 35 the point C represents the depth to which the planing action of the sea extends, and if Fig. 35 represents the same coast as Fig. 30, p. 126, but after the sea has cut back the cliff from B in Fig. 30 to A, the force of the waves will be checked, because as the depth at C remains the same, and the distance CF (Fig. 35) is greater than the distance CE in Fig. 30, the slope CF must be gentler than CE. Hence we find that cliffs rarely exceed a height of 500 feet; for even if we assume that the country had

[1] *Proc. Inst. Civ. Eng.* vol. xl. 1875.

an original slope of as much as 20°, a cliff of 150 feet would give a littoral platform nearly 800 yards in width, a distance which would greatly diminish the force of the waves. On this the breadth attained by the platform greatly depends. Hence off the west coast of Ireland, where the coast is exposed to the open Atlantic, there is a wide plateau, often without any beach.

Moreover, it very generally happens that the waves heap up sand-hills, forming dunes (Fig. 35, G),

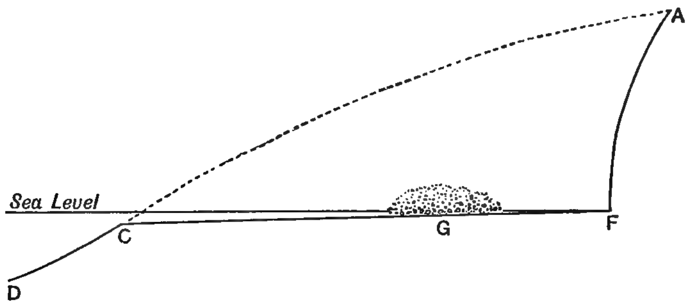


Fig. 35.—Diagram to illustrate action of Waves on a Sea-shore.

and leaving a marsh behind them, thus building a wall against themselves, as will be more particularly described later on (p. 150).

The depth to which the bottom is disturbed by waves will no doubt differ very much according to circumstances. The movement of the waves is greatest at the surface, and gradually diminishes downwards; the action is, moreover, often checked by the growth of seaweeds. Messrs. Weber have found by experiment that the oscillation continues to 350 times the height of the wave, where, however, it would be quite trifling. At a depth equal to one-

fourth of a wave length, or double the height of the wave, the movement would be reduced to one-half; and at a depth of a whole wave length it would be only ·002 of that at the surface. Sir J. Coode, in the same memoir, mentions that in 1852 he found the pebbles of the Chesil Bank at a depth of a very few fathoms encrusted with living barnacles, showing that they had not been disturbed for some time. Repeating his observations, however, a year or two later, he found the pebbles quite clean, every barnacle having been ground off.

The fishermen at Lands End often find their lobster-pots filled with shingle during heavy ground-swells at a depth of 30 fathoms;[1] sand has been observed to be ripple-marked at a depth of 500 feet; and M. Vionnois states that in the bay of St. Jean de Luz the agitation during storms is felt even at a depth of 300 fathoms.[2]

The tides also exercise an important influence by carrying off materials washed down by the waves. Lyell mentions that in Sheringham harbour, on the Norfolk coast, there was in 1829 a depth of 20 feet of water, where fifty years before there had been a cliff 50 feet high. This was evidently due to tidal currents; and it is clear that the destruction of land by the sea would have been much less than has actually occurred, if the materials washed down had not been so quickly carried away by the tides which sweep round our coast.

If in any part of the coast forming part, say,

[1] *Proc. Inst. Civ. Eng.* vol. xl. 1875. [2] *Ibid.* vol. xii. 1853.

of a wide bay, there is a series of hard (H) and soft (S) strata (Fig. 36) approximately at right angles to the coast and at any moderate height, the result of sea action will be that the waves between high- and low-water mark will destroy the soft strata more rapidly than the harder. Consequently the coast-line at high-water will follow the waved line CD. On the other hand, the low-water may still follow the original line AB. Hence the water-line at high- and low-water may be very different. This is a condition often found along our shores, and hence the occurrence so frequent on our coasts of headlands which are impassable at or near high-water, and between which are sandy or shingly coves.

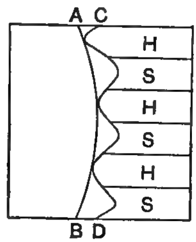


Fig. 36.—Diagram to illustrate effect of hard and soft strata on a shore-line at high- and low-water. H H, hard strata; S S, soft strata; AB, low-water line; CD, high-water line.

THE SHINGLE

The belt occupied by shore-drift is the beach. Its upper limit is generally a few feet above high-water mark, and it extends below the water a little beyond the line where the great storm-waves break. If the coast is steep this will be close in-shore, but if it is shelving it may be at a considerable distance.

The zone of depth within which the movement of the beach takes place is but narrow; the pebbles and sand travel backwards and forwards, until they are

either thrown up or carried down so far as to attain a position of rest. The shingle is sometimes altogether washed away, and at one time or another almost every portion of our south coast may be found in the condition of bare rock, quite free from sand or shingle.

On the other hand, pebbles are often heaped up 8 to 10 feet above high-water, and the Chesil Bank at the Portland end is no less than 35 feet above high-water at spring-tides.

The pebbles of the beach are by no means all derived from the cliff. When the tidal wave reaches the shallower water near the shore, it becomes a wave of translation and carries sand and stones and even large boulders with it. The result of this on some shores is that stones are rolled in from a considerable depth and thrown on the shore.

Seaweeds, moreover, contribute not a little to the same result; they attach themselves to the rock, and grow towards the surface, many of them being floated upwards by the presence of innumerable air-vessels. The waves as they pass drag the weeds with them, tear up the stones, and throw them on the shore. Some beaches are almost entirely supplied with pebbles in this way by seaweeds.

The general movement of shingle on our south coast is from west to east; and when the coast is protected by groynes, it will be observed that it is generally heaped up on the west side of each groyne, and that the larger pebbles lie nearest to the groyne. So also on the Chesil Bank, where the Isle of Portland acts as a gigantic "groyne," the highest part of

the bank and the biggest pebbles are at the Portland or eastern end.

It seems at first sight rather anomalous that the larger stones should move farther and faster than the smaller. This is due partly to the fact that the smaller pebbles project less, their upper sides form part of the general surface, so that they offer little purchase to the water, and each pebble would have to be raised up before it could be moved along. The larger ones, on the contrary, lie on the others, and can, so to say, be slipped along. Moreover, the larger stones have greater weight and therefore greater momentum.

It is of course the forward movement of the wave which carries pebbles and sand on to a shore, while the return movement tends to drag them down again, and this being weaker than the forward movement, there is a tendency for the larger stones to be heaped up on the higher part of the beach.

Here they will form a ridge, the steepness of which on the seaward side will depend on the size of the stones. If they were all approximately of one size, and if we assume that the backwash of the wave was not sufficiently powerful to move them, they might stand at some such angle as that shown in Fig. 37. Now, suppose that, other circumstances remaining the same, the pebbles were smaller, some of them would then be carried down, until some such slope as that in Fig. 38 was acquired, when again the weight of the stones and the force of the waves acquired an equilibrium, and they would remain in place. Suppose, once more, the size of the

Fig. 3 .

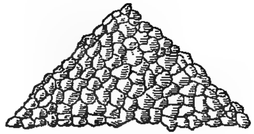


Fig. 38.

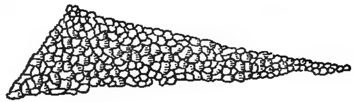


Fig. 39.

Fig 40.

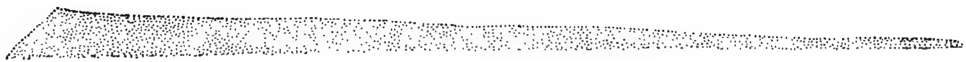
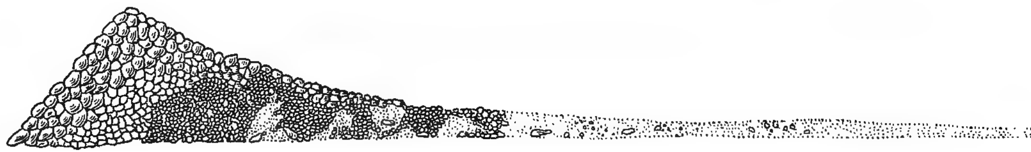


Fig. 41.



Figs. 37 to 41.—Diagrams to show arrangement of materials on a Beach.

pebbles were reduced, the slope would again be diminished, as in Fig. 39; and if the materials were sand the slope would be reduced to that with which we are familiar on so many shores (Fig. 40). This is why beds of shingle stand at a high angle, while sandy shores are almost flat.

Lastly, if the materials consisted of stones, etc., of various sizes (Fig. 41), the largest would be found highest, *i.e.* at high-water level, and the remainder would be sorted down according to sizes, the smallest being the lowest.

The pebbles of sea-beaches vary greatly in size and character, but as a rule consist of flat ovoids, very different from the rounded pebbles of rivers, or the angular fragments of glacial drifts.

The beach on any shore accumulates with off-shore winds, and is scoured away during on-shore winds, and especially if there is a heavy ground-swell. If the waves follow one another rapidly, say ten or any greater number in a minute, the water when the wave breaks falls from the crest on to the returning water of the preceding wave, and its force is thus diminished. But if, on the contrary, the number of waves is less—say seven or any smaller number in a minute, then the water of any former wave has retired before the next one breaks, hence the water from the crest of each wave falls directly on the shingle and tends to sweep it back.

In any beach, at least if the winds have been off-shore, or just along the shore, the largest pebbles are about at the level of the previous high-water, or so far

above it as the waves could carry them, and the sizes then decrease to the level of low-water.[1] On the other hand, after heavy on-shore winds or a ground-swell, the large shingle may be entirely scoured away.

The beach at Folkestone, after a ground-swell, so far as it has been affected by the waves, has a slope of 1 in 9; but after off-shore winds, for two or three days, during which the shingle has accumulated, the angle rises to 1 in $3\frac{1}{2}$ or 4.

When the shore slopes gradually the shingle is thrown up into a ridge, as may be seen, though not so clearly as I could wish, in the following figure (Fig. 42) of Lydstep Cove, near Tenby, which shows also the beautiful curve so characteristic of shingle beaches, the perpendicular cliffs and flat surface so generally presented by the Carboniferous Limestone of that district, and which perhaps represents a sea-plain of ancient times, though probably of no great geological antiquity.

Beaches generally show two terraces or two lines of seaweed, one marking the high-water at the last spring-tide, one the high-water line of the last tide. Between them are sometimes one or more others, showing the high-water level during some recent storm. The entire beach will only be smooth if there has been an oblique gale of wind at high-water on the highest spring-tide.

We may say that, as a general rule, the materials of the sea-bottom become finer and finer as the depth of water and the distance from land increases.

[1] Coode, *Proc. Inst. Civ. Eng.* vol. xii. 1853.

Fig. 42.—Lydstep Cove, near Tenby. Showing the curved pebble ridge, and in the distance the flat, abraded surface of Carboniferous Limestone.

This has long been known. Lord Anson, in his account of his voyage (1740-47), tells us he often, when navigating unknown seas in foggy weather, relied on the evidence derived from the character of the bottom as a fair indication of the distance from land.

According to his statements—

12-40	fathoms	give	coarse sand and gravel.
40-60	„	„	sand with broken shells.
60-80	„	„	fine sand, mud, and ooze.

These considerations obviously throw much light on the conditions under which strata have been deposited. Along our coasts at a depth of about 90 fathoms the bottom consists of a dark impalpable mud, resembling the material of the Lias or the London Clay; while at a somewhat less depth are tracts of clean white sand, which if raised above the water-level would give a country closely resembling the Bagshot Sands or the Lower Greensand.

If, then, we imagine a valley depressed so that the lower end was occupied by sea to a depth of 100 fathoms, the products of wave destruction would be carried outwards and arranged in zones according to the size and weight of the particles; and if followed from the upper end outwards, the deposits would present a gradation from coarser to finer materials. Gradually the accumulation of materials would raise the bottom so that the water would become shallower; the result would be that fine sand would be deposited on mud, coarse sand on fine, gravel on coarse sand.

If the area subsided so that the water became deeper, the reverse would take place, fine sand might be deposited on coarse, and mud on fine sand. In either case the beds would overlap one another.

Some such process as this explains the succession of clay, sand, and gravel which we see so often.

Materials derived from the shore may be said to extend from the littoral zone down to a depth of 2000 feet and more, and to a distance of 60 to 300 miles from shore. They are confined, therefore, to a comparatively narrow belt round the margins of continents and islands.

To these combined actions—the shaving of the shore and the spreading of the materials thus obtained—is perhaps due the great marine plain or shelf which extends to the west of our shores, and the edge of which drops suddenly to the depths of the Atlantic.[1]

No one can fail to have noticed the tendency of shingle to arrange itself in festoons (Fig. 43) along the shore, forming raised wedges or ridges which taper towards the sea, leaving between them bays, perhaps 20 feet wide, and from a few inches to 2 to 3 feet in depth, running up to high-water mark. This structure is probably due to the crossing of waves, the result of which is that the water presents an indented front, and runs up the beach in long tongues, pushing forward the sand and small stones, while the recoil of the wave drags back the sand, but has not power to move the pebbles. The next wave naturally runs up the little bay thus formed, which gives the water

[1] See J. Geikie's *Fragments of Earth Lore.*

Fig. 43.—Freshwater Bay, Isle of Wight.

greater depth and consequently more power, thus somewhat enlarging the bay.

The largest pebbles are thrown farthest, and the retiring wave forms a talus of sand, which diminishes in fineness and in inclination downwards. Such festoons or scallops sometimes extend in nearly regular succession for miles.

There is also often a sharp boundary-line between the shingle and the sand. The reason of this appears to be that the returning wave, which is at first for a moment stationary, increases its velocity as it descends, and consequently its power of transport. As, however, the inclination of the shore decreases the friction increases, the velocity is checked, and consequently the power of transport is diminished. The line where the velocity ceases to increase and commences to diminish appears to form the boundary between the deposit of shingle and that of sand, and along this line the deposit of shells and shell fragments concentrates itself.

THE SANDS

On a shelving shore below the shingle there is generally a more or less wide expanse of sand, which constitutes so great an attraction—forming a most interesting playground for children, and affording excellent opportunities for bathing.

Sand consists of silica, the one of all our common minerals which is the least affected by the agents of decay. It is, moreover, extremely hard, and the

grains lying with their faces to one another hold a film of water between them, which keeps them from actually touching. It is almost impossible to squeeze this water out, and as a consequence there is very little friction between the sides. Hence sea-sand remains angular. On the other hand, desert-sand, which is dry, when blown about by the wind soon becomes rounded.

Sands do not, of course, form an essential feature of all shores, but they are of very general occurrence. Shore-drift nearly always contains sand, and is sometimes almost entirely composed of it. If the cliffs contained clay and sandstone, or chalk and flint, the clay and chalk are gradually eliminated. The clay becomes disintegrated into fine particles, which are carried into deeper water by the undertow, the chalk is dissolved, and the broken flints and pounded sandstone form sand.

Where the shore is flat, sands often form a wide expanse, and the on-shore wind, drying the surface, drives it inland, and gives rise to sand-dunes. During spring-tides especially, wide belts are exposed, and the area of sand is thus greater than we should expect if we only see the locality during ordinary tides.

On many parts of our coast the sands have covered a considerable area, and form hills more than a hundred feet in height. Such sand-dunes are picturesque objects, and often present quite a mountainous appearance, especially towards sunset.

They form generally a comparatively narrow belt,

Fig. 44.—Sand-dunes between sea and marsh, Penally, South Wales.

—a sort of natural embankment—and the low ground beyond, from which the sea has thus shut itself out, forms first a lagoon and then a marsh, which is gradually raised by the growth of water-plants, and eventually forms rich corn-land. Fig. 44 shows the sand-dunes, with low ground behind, between Tenby and Penally; and Fig. 45 gives a sketch-map of the Welsh coast between Swansea and Aberavon, showing

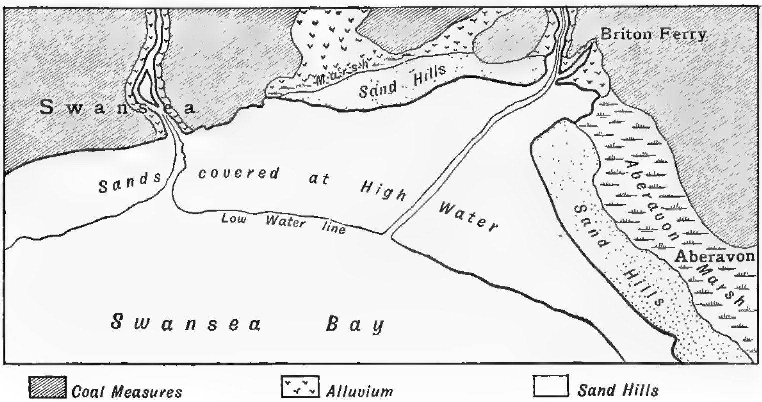


Fig. 45.—Map of part of Swansea Bay.

the tracts of sand which are left dry at low-water, the sand-dunes, locally known as burrows, and the marsh behind. Similar "burrows" in front of marshes occur at Margam, Oxwich Bay, Rhossili Bay, Llanrhidian Sands, Pendre Burrows, and many other places in the neighbourhood, as well as along other parts of our coast.

Sand-dunes flank the shore for miles along many parts of our shores. Along the east coast of the United States there is an almost continuous waterway enclosed by such banks, and extending in some cases for hundreds of miles.

In fact, Shaler estimates[1] that nine-tenths of the coast-line of the world is fringed by sands.

The presence or absence of sand-dunes depends mainly on the nature of the rocks along the coast, but it is also influenced by the configuration of the surface, and by the direction of the most prevalent winds. If they are on-shore they blow the sand inland at low tides, heap up dunes, and tend to drive them inland. Whole villages have in some cases thus been buried.

On the contrary, if the wind is generally off-shore, the sand is continually blown back into the sea, so that no dunes can be formed.

If it is driven inland, the sand, as soon as it reaches the top of the beach, comes on a more or less uneven surface, with bushes and grass, between the stems of which it is heaped up. Certain grasses, sedges, and other plants are specially adapted to sand. Their roots mat it together, it accumulates between them, and is thus heaped up into hills sometimes several hundred feet in height. Between Cape Bogador and Cape Verde on the African coast the dunes are said to reach a height of 600 feet.[2]

The source of all this sand is a problem of high interest, in consequence of the important part it plays on the earth's surface. Much of it is derived from the Granites, the Gneisses, and Crystalline Schists; the waves are the agents, and the sea-shore is the workshop in which it is prepared. The softer

[1] *Nat. Geog. Monographs*, 1895.

[2] Richthofen, *Führer f. Forschungsreisende.*

rocks are worn to dust; and though the sand grains on sea-shores retain their angles, those in dry deserts, as already mentioned, clashing together under the action of the wind, have their angles rubbed off and are turned into dust. This æolian dust is a valuable fertiliser, and to the natives of Central Asia the dust of the desert is almost as important as the Nile mud to the people of Egypt. The presence and absence of these æolian deposits constitutes the difference between steppes and deserts,—the former are regions on which dust has for ages been deposited, the latter those from which it has been removed.

The mere degradation of sea-cliffs is quite inadequate to account for the masses of shingle and sand along our shores, and a great part no doubt consists of materials brought down by the glaciers and torrents of the Ice Age, worn, however, of course, and rearranged by the waves. Even so, however, the quantity of sand, consisting almost entirely of quartz grains of nearly uniform size, is very surprising.

OUTLINE OF COAST

It used to be assumed that all the inequalities of the coast were due to alternations of harder and softer rocks. James Geikie, for instance, says, "the harder and less readily demolished rocks will form headlands, while shallow bays will be scooped out of the more yielding masses."[1] Some recent writers seem to have gone to the other extreme, and regard

[1] *Fragments of Earth Lore.*

all bays as drowned valleys. Probably, however, some bays are due to the one cause, some to the other.

The first effect of the action of waves on a shore would no doubt be more considerable on soft or much-fractured rocks, than on others which were harder or more compact. Caves will generally be found to be due to the presence of softer layers, or rock which has been much broken up. Some of the smaller indentations of the coast may probably be thus accounted for, as in the case of Lulworth Cove (Fig. 28, p. 122, and Fig. 29, p. 124). So far, however, as the final results are concerned, the general effect of waves and storms will be to wear down the projecting headlands, to deposit the materials in the bays, and thus gradually to reduce the indentations, and to produce a more even coast-line.

Indirectly, however, the indentations of the coast are due to the hardness and compactness, or softness of the rocks, because aerial influences have acted more on the latter. Hence the surface of the ground would be lowered more in the one case than in the other; and if such a district be submerged, as for instance in Fig. 46, where the curved lines represent contours, to a depth of say 200 feet, the higher parts would stand out as headlands, while the softer strata would give rise to a bay.

For instance, Mounts Bay on the south of Cornwall corresponds to a depression in the land running to St. Ives Bay on the north coast, and a depression of little more than 100 feet would bring

the whole valley down to the sea-level and turn the Lands End district into an island.

In fact, the action of the sea tends finally to abolish, not to form, bays, and the result is rather to make even outlines than to excavate any indentations in the outline of the coast.

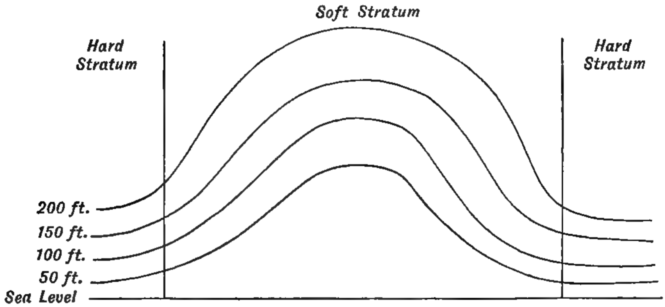


Fig. 46.—Diagram in illustration of the formation of Bays.

TRANSPORT OF MATERIALS ALONG-SHORE

The spoils of the shore are gradually carried by the retiring waves down into the sea; but if the waste of a coast is more than the waves can carry down into deep water, the materials are transported along-shore in the direction of the prevalent wind.

In many places along our coasts the shore is protected by groynes, or lines of board, supported by posts, running straight across the beach and sloping down towards the sea. The object is to check the shingle from travelling, and it will be observed that it generally lies much higher on one side of the groyne than on the other. Even a light breeze, if it is along-shore or oblique to it, will cause the waves to break

obliquely to the shore, and consequently will heap up the beach down-wind against the groyne, for as the wind blows the wave flows and the shingle goes. But though the wave often breaks obliquely on the shore, it recedes straight downwards, so that the pebbles travel gradually along the shore in the prevalent direction of the waves.

Thus the shingle, as Palmer showed many years ago,[1] travels in a series of right-angled triangles, being driven diagonally up the beach, and then dragged straight down by the recoil of the wave.

It will also be observed that the pebbles tend to diminish in size from the leeward groyne to the windward groyne. The cause of this has already been suggested (ante, p. 141).

It must not be supposed that the shingle has travelled far. Along our south-east coast the long range of Chalk cliffs accounts for a considerable uniformity, but on other parts of our coast nearly every bay has its own peculiar shingle. That in Slapton Bay, Devonshire, for instance, differs from those on almost any other part of the same coast. "It consists[2] almost entirely of white quartz pebbles, resembling pears in shape, and averaging from an eighth to a quarter of an inch in diameter. This shingle not only covers the beach, but has been thrown up into a bank, the top of which is above the level of high tides, and has drifted across a deep indent in the bay, into which two fresh-water streams discharge, entirely closing this from the sea and

[1] *Phil. Trans.* vol. cxxv. 1834.

[2] Wheeler, *Nature*, vol. lxii. 1900.

forming it into a fresh-water lake about two miles long. The quartz pebbles of Slapton Bay do not drift beyond the eastern horn of the bay, and are not to be found in the next recess. . . .

"The beach at Budleigh Salterton is strewn with quartzite boulders and pebbles derived from a large bed contained in the cliffs bordering this part of the bay. These pebbles are of a pink colour, some having marks on them like blood-spots. No stones of a similar character are found in the next bay, the drift being stopped by some rock ledge which projects out from Otterton Point and forms a natural groyne. The shingle in front of Seaton consists almost entirely of the chert and flint derived from the rock at Beer Head."

The line of flint shingle along the French coast at the eastern end of the Channel is almost coterminous with the Chalk cliffs.

When bays recede far inland, the current generally sweeps across from one headland to the other. Along the line between the still and the moving water shingle and sand are deposited, gradually forming a bar and enclosing a lagoon. Outside the bar, on the contrary, the water is deep. Again, if a headland supplies more material than the waves can carry out to deep water, they will arrange it in the form of a spit streaming away from the cape.

The ocean currents sometimes form great eddies, between which are triangular spaces of comparatively dead water, and in these of course there is a tendency to deposit material. This by degrees produces

triangular shoals, gradually accumulating into spits, and forming forelands.

Gulliver gives the following diagram (Fig. 47) as illustrating the formation of such a spit or "cusp." The dotted line indicates the former outline of the shore.

We may distinguish in the formation of such a foreland three stages.

First, a bar, which often projects outwards, assuming the form of a V; secondly, a ridge, also frequently V-shaped, with lower ground behind, in many cases

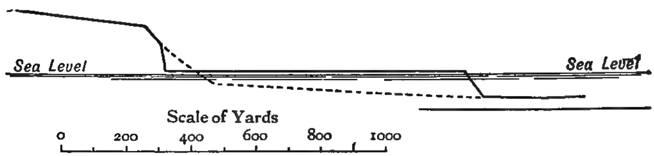


Fig. 47.—Profile of a Tidal Cusp. The ratio of the vertical to the horizontal scale is 2 to 1.

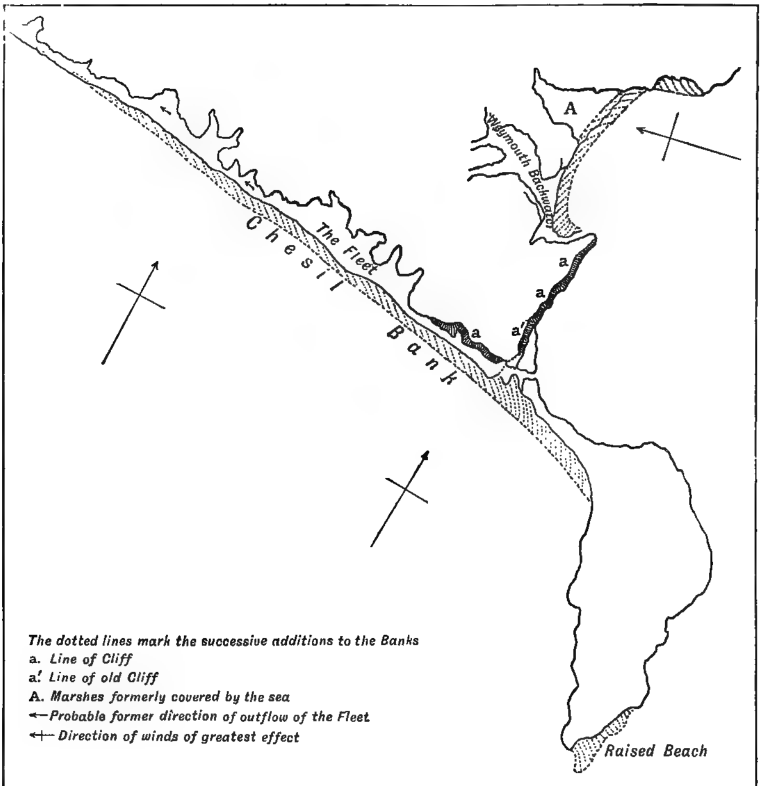
enclosing one or more lagoons; and thirdly a final stage, in which the whole area between the bar and the cliff has become filled up to a height somewhat above the mean sea-level.

In the same way islands may be, and often are, tied to the land by beds of shingle built up by the sea. The Isle of Portland has in this way been converted into a peninsula by the Chesil Bank.

At first the bar is a narrow belt with a wide expanse of water behind it. Gradually, however, the bar widens, the lagoon behind silts up and forms dwindling lakes. Good illustrations of such coasts are afforded by the shores of Holland, Germany, the United States, etc.

The greatest accumulation of shingle in the United

Kingdom is the Chesil[1] Bank (Fig. 48). It was justly described by Leland long ago as "a *prodigious* heap of pebbles," and is one of the most remarkable features of the south coast of England. It is



Prestwich. Proc. Inst. Civil Eng. 1875.

Fig. 48.—Plan of the Chesil Bank and Isle of Portland.

indeed probably the most extensive and extraordinary accumulation of shingle in the world. It is about 18 miles in length, extending from Abbotsbury to the Isle of Portland.

[1] From the Anglo-Saxon "Ceosel," flint.

At the Abbotsbury (west) end it is 170 yards wide at the level of low-water in ordinary spring-tides, 23 feet in height, and extends to a depth of 36 feet below high-water mark; while at the Portland end it is 200 yards in width, 43 feet in height, and extends to 48 feet below high-water. The shingle gradually decreases in size from east to west. It consists mainly of Chalk flints with a small proportion of Red Sandstone pebbles, some yellow with blood-coloured spots, and some of jasper from Aylesbere Hill on the River Otter. The bank consists generally of shingle to a depth of 10 to 15 feet, where sand commences and gradually increases in proportion to the pebbles.

Moreover, the form of the pebbles is different, those at the Portland end being flattened ovoids, at the Abbotsbury spherical and large below water, small above.

There has been much difference of opinion whether the shingle travels from east to west or from west to east. The latter view was advocated by Sir John Coode,[1] Sir John Rennie, Sir John Hawkshaw, and Mr. Gregory. Sir J. Prestwich[2] and Sir G. Airy, on the contrary, maintained that the shingle travels from east to west.

This view is also prevalent among the fishermen of the locality, and is based on the idea that the stones are gradually worn down, and consequently that the smaller ones are those that have travelled farthest.

[1] *Proc. Inst. Civ. Eng.* vol. xii. 1853.
[2] *Ibid.* vol. xl. 1875.

The diminution in size is, however, much more rapid than the distance would account for. The shingle at Dungeness has travelled past Langley Point, a distance of 30 miles, and yet there is no perceptible diminution in size. On the Chesil Bank there are, moreover, large stones sprinkled among the shingle at the Abbotsbury end, though they become more numerous towards Portland. In fact, as Mellard Reade said, "the pebbles followed the same law that determined the size of the bank itself, for where the bank was the highest and broadest, the pebbles were the largest."

It has been already shown (ante, p. 141) that large pebbles on a shore travel more rapidly than smaller ones. Whitaker has pointed out that where there are groynes across a beach the larger stones are carried farthest, and deposited on the higher part of the beach. Every interval between two groynes repeats the phenomenon exhibited by the Chesil Bank.

Moreover, the general trend of the shingle on our southern coast is from west to east. The view, therefore, originally advocated by Sir J. Coode was probably correct, and here as elsewhere along the English Channel the progression is from the west towards the east.

For the first 6 miles of its course the Chesil Bank keeps in contact with the coast, but then for 8 miles maintains a beautifully even curve at a distance of 200 to 1000 yards from the mainland, enclosing between itself and the shore a shallow salt-

water and brackish lagoon known as the Fleet. For the last 2 miles the beach strikes boldly out to sea to join itself on to Portland.[1]

The shore of the Fleet is quite unlike others in the neighbourhood; it is meandering in outline, has little cliff, and that only of a slight elevation.[2] It appears to be a remnant of the old coast, cut off by the Chesil Bank.[3]

Hurst Point, again, at the entrance of the Solent, is a straight bank of shingle 2 miles long, resting on a base of clay, and ending in a steep submarine cliff, 200 feet in height.[4]

One of the finest spreads of shingle in the United Kingdom (Fig. 49) is on the left side of the Ore or Alde in Suffolk, reaching north-eastward to Aldeburgh, and which is still increasing by the deposit of shingle at its south-western end. A chart of the time of Henry VIII. shows distinctly that the mouth of Orford Haven was then opposite Orford Castle; whilst a chart of the time of Elizabeth shows a considerable south-westerly progression. When the Ordnance Map was made (published 1838) North Weir Point, as the end of the spit is called, was about east of Hollesley.

It consists of a series of curved concentric ridges or "fulls" (Fig. 49) sweeping round and forming a projecting cape or "Ness" in advance of the general coast-line. The triangular projection encloses salt

[1] Strahan, *Mem. Geol. Surv.*, Isle of Purbeck.
[2] Whitaker, *Proc. Inst. Civ. Eng.* vol. xl. 1875.
[3] Prestwich, *ibid.*
[4] Redman, *Proc. Inst. Civ. Eng.* vol. xi. 1852.

marshes, and extends from Aldeburgh to Landguard Point.

Successive ridges or waves of shingle are, indeed, a marked character of such headlands.

Under ordinary circumstances, and when the shore-line is stationary, each succeeding tide obliter-

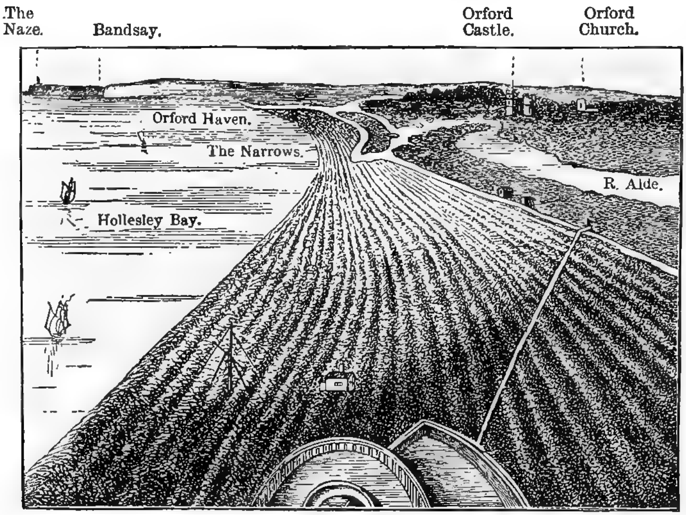


Fig. 49.—Orfordness from the high lighthouse to the Naze, looking S.W. The direction of the "fulls" along Hollesley Bay is E. by N. to W. by S.[1]

ates the ridge made by the last; but when the shore is encroaching on the sea some great storm will throw up the shingle in the form of a ridge, after which another accumulation commences, and eventually forms another ridge.

The development of this beach, however, has not been invariably progressive, breaches made by storms having sometimes given a temporary exit for the

[1] *Proc. Inst. Civ. Eng.* vol. xxiii. 1864.

waters of the Ore and of the Butley river at the Upper Narrows, where the part of the channel to the south would be partially closed.

The Ordnance Map of 1838 shows separate knolls of shingle for a mile southwards from North Weir Point. The point no longer exists as there shown, the knolls having been united into a continuous bank, as marked on the Geological Survey Map, which has been corrected from a later survey.[1]

Lowestoft harbour is mainly artificial, having been formed by means of a connecting cut and a lock into Lake Lothing, and its depth is maintained by dredging. At Lowestoft Ness the foreshore is mainly sand. As usual in such cases there is deep water (6 fathoms) close to the Ness.

The sands of Yarmouth, like those of Lowestoft, have in recent years been comparatively stationary. The town of Yarmouth stands on a spit of sea-driven sand, thrown up in 1008 A.D., and which crosses the outfalls of the Waveney and the Yare, enclosing a large mere—Breydon Water, the outlet of which, like that of other Suffolk rivers, is being constantly forced southwards by the accumulation of sand from the north.

From Winterton to Ness Point there is an inner and outer range of sand-hills,—the inner or land range comparatively low, the outer one 50 to 60 feet in height, rising sometimes to 100 — tossed into wild disorder, with deep basins and beach in the hollows. The old tower of Eccles has been immortalised by

[1] Whitaker, *Mem. Geol. Surv.*, Ipswich.

Lyell's graphic description. The sand-hills reached to the top of the tower, which, however, has since been destroyed by a storm.

Dungeness is another great deposit of the same character. It presents more than 20 "fulls," and may be taken as a type of such deposits, which occur all over the world. There is, for instance, New Dungeness, on the United States coast; and in the eastern entrance to the Straits of Magellan is another "Dungeness," so named by some English seaman, perhaps from the coast of Kent.[1]

On our east coast the general trend of the beach is from north to south; it tends to form a barrier across all the estuaries, harbours, rivers, or streams, and to turn the course of the rivers southwards. This is exemplified at the present day at the mouth of the Humber, and at Great Yarmouth and Lowestoft, the River Yare being diverted a distance of 2¾ miles to Gorleston, where it has an artificial outlet, and was previously diverted to a much greater distance farther south.[2] The Alde, as already mentioned, is also deflected to a considerable distance southwards. On our south coast the drift is from west to east; the Chesil Beach has diverted the course of several small streams. Spits of shingle have also been formed across the estuaries of the Teign and the Exe, across Christchurch harbour, and in many other places.

In some cases where a stream is encased in a deep

[1] Gulliver, *Proc. Am. Acad. of Arts and Sci.* 1899.

[2] *Mem. Geol. Surv.*, Yarmouth.

valley, and cannot therefore be diverted, it is completely blocked out from the sea, to which it finds its way through the shingle. This is the case, for instance, with the river at Sidmouth, with several streams on our eastern coast, with the brook which reaches the sea at Pwlldu, through the Mumbles and Oxwich Bay, etc. The Cuckmere, again, has an uncertain outlet through the shingle between Beachy Head and Seaford.

Along most of our coast there is a more or less rapid loss of land from the action of the sea. It has, however, already been shown (ante, p. 150) that in many cases after a certain time the sea will begin to build up sand-hills, and shut itself out. Moreover, even if the tides and currents carried away all surplus shingle and sand, still the process would generally be slow.

It must also be remembered that while along much of our coast the sea is gaining on the land, there are other important tracts where the reverse is the case, and land is being reclaimed from the sea.

For instance, the average rate of waste along the Holderness coast is estimated at about $2\frac{1}{4}$ yards a year for the last 200 years. On the other hand, there is by no means a loss of land to that extent. The amount of material thus annually removed from the coast between Flamborough Head and the Humber is estimated at about 6,000,000 tons, of which a great part is sand and mud. This is carried southwards, and much of it is washed into the estuary of the Humber, while some is carried into the Wash. The silt and

mud, though not causing any serious diminution in the waterway for ships, is deposited on and gradually raises the side banks. Thus tract after tract has gradually risen to near the level of high-water. The growth of salt marsh-plants then begins to bind the mud, and when the marsh has risen to within a foot or two of ordinary high-water mark the growth changes from samphire to sea-lavender, sea-blite, and sea-purslane, then to thin wiry grass, and afterwards to better kinds. It can then be profitably protected by embankments, and becomes valuable land.

The amount of land lost on the Holderness coast in the last 200 years is estimated at 11 square miles, while the amount gained in the Humber has been 15 square miles, to which probably we might fairly add an even larger area in the Wash. Beazeley states that in the estuary of the Humber about 290 square miles have been reclaimed, and in the Fens of Lincolnshire 680,000 acres or over 1000 square miles.[1] Thus for every square mile washed away along the Holderness coast three square miles have been gained in the Humber and the Wash. Moreover, while much of the land lost was poor, that gained is exceptionally rich. From a national point of view this is consolatory, though it is little comfort to those whose property is being so rapidly swallowed up by the sea.

Spurn Point, at the entrance to the Humber, is due to the southerly drifting of the mud and sand derived from the wear and tear of the Holderness

[1] *On the Reclamation of Land.* The cost, however, has been very large.

coast. From old maps and records it appears to have been entirely formed in the last 300 years; and as there is no reason to suppose that anything coarser than sand can cross the mouth of the Humber, what became of the southward travelling beach in former times? The answer seems to be that when the point has reached a certain distance south, the neck becomes narrow, the sea at length breaks through, and, the river taking this short-cut, the point becomes an island, which at last is transferred from Yorkshire to Lincolnshire, after which the same process repeats itself.[1]

On our south coast again, though in places the sea is encroaching rapidly, and on the whole no doubt there is a considerable balance of loss, still in places the reverse is the case. Romney Marsh has been thus "inned" from the sea: in 893 the Danish fleet sailed up to Appledore, and the increase of Dungeness is said to be as much as 6 feet yearly.[2]

CHANGES OF LEVEL

We have hitherto considered the coast as if land and water remained permanently at the same level. This is, however, by no means the case.

There is, as we have seen in Chapter II., abundant evidence that at a geologically recent, though measured in years a very distant, period, England was submerged to a depth of several hundred feet.

Subsequently it rose not only to the present level,

[1] Reid, *Mem. Geol. Surv.*, Holderness.

[2] Redman, *Proc. Inst. Civ. Eng.* vol. xi. 1852.

but some 400 or 500 feet higher, and our river-valleys (ante, p. 105) were excavated to that depth below the present sea-level.

In Fig. 35 (ante, p. 137) I have given a section of a sea-plateau and cliff. If such a shore were raised, the same features might be repeated at a higher level.

Fig. 50 gives a section of a raised coast. ACEF is the old surface, AB is the present shore, and BC the present cliff; CD is a former shore-plateau, and

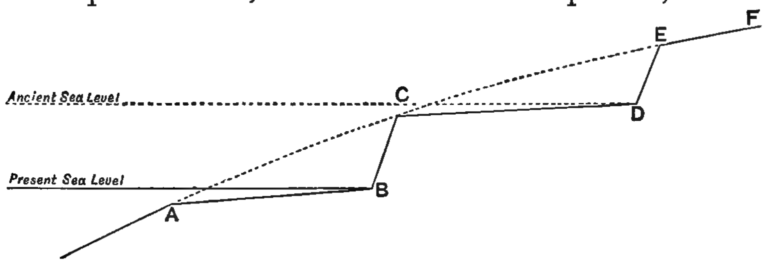


Fig. 50.—Diagram of a Shore showing existing and raised Terrace. AB, present shore-platform; BC, present cliff; CD, former shore-platform; DE, former cliff.

DE a former cliff. In some cases more than two such cliffs are present. Terraces so formed are frequent round our coasts (see ante, p. 112). Even if there is no cliff there is generally a marked difference of angle where the old land surface joins the sea-plateau. This is known as the "fall line," and as it generally forms the limit of navigation in rivers it often determines the site of cities.

If, on the contrary, the land is sinking relatively to the sea, the results, being under water, are of course less evident. The result, however, would be a gradually widening and gently sloping plain. This

was first pointed out by Ramsay in 1847, though he does not appear to have realised its full significance.

At Margate, for instance, and elsewhere round the Isle of Thanet, is a broad sea-plateau, most of which is exposed at low-water, and which reaches to the foot of the cliff; while the surface of the island itself forms a second and higher plateau, formed when the land stood at a lower level relatively to the sea.

SHORE LIFE

Among the most interesting of the common shore objects are lumps, about the size of a fist, of yellowish, parchment-like capsules, each about half-an-inch in diameter, and each containing about 500 whelks' eggs; the eggs of dog-fish, small, flat, squarish black bags with a long tendril at each corner, by which they are attached to seaweeds, etc.; fronds of flustra, generally taken for seaweeds, but which are really animal, and may be recognised by their rough feel to the touch, due to a number of minute cells, just visible to the naked eye, and each containing an animal, the whole group, however, being connected together and forming a colony; zoophytes, like miniature cypresses and firs; many kinds of shells; brown, red, and green seaweeds; etc. etc.

At about the mean high-water level commence the olive seaweeds, and in places the rocks are covered with a grey crust of barnacles, animals allied in reality to, though differing widely from, lobsters and

crabs. Their feathery legs, which form a sort of net by means of which they capture their prey, gave rise to a ridiculous idea that they were the origin of barnacle geese, which, being therefore regarded as fish, were allowed to be eaten in Lent!

Scattered about above the high-water line are often plants of blue sea-holly, or yellow-flowered horned poppies, sea-kale, sea convolvulus, saltwort, artemisia, and various grasses; on sandy shores the marram grass is abundant, and very useful in binding the sand together.

On flat muddy shores indications of land vegetation first appear at about the level of high-water at neap-tides, and consist mainly of samphire. Grass commences at about a foot higher.

CONCLUSION

The first result of sea action on a coast is to form bays and headlands, the weaker strata being more rapidly eaten away than those that are harder and tougher. As, however, more and more shingle, sand, and mud accumulate, the bays are again filled up.

Below water the sea action gradually forms a marine plain, shelving gradually from the shore out to sea.

When this shelf became sufficiently wide, it might so far break the force of the waves that the coarser materials would not be carried to the foot of the cliff, but would be heaped up at some distance from it,

leaving a belt of shallow water between this ridge and the old coast-line. As a matter of fact we find in many places along our coast a fringe of dunes, or links (so often associated with golf that when we speak of "links," we often only mean a place arranged for that game), with marshy ground between it and the land.

Thus the present contour of our coast is evidence of considerable antiquity. There is no gradual descent of the surface towards the sea-margin, but ranges of hills, sometimes increasing in altitude towards the shore, and terminating in cliffs. It must have taken a long time for the sea to have eaten back to the present site of the coast-line.

The nature of the coast-line exercises a great influence on the character and history of nations. Good harbours especially are of great importance, and among the principal requisites are,—protection against the prevalent winds and the violence of the waves, depth of water, absence of sand-banks and sunken rocks, good anchorage, and easy access both by land and water.

The coast of Africa follows closely the great ocean drop, and the absence of bays and good harbours is no doubt one of the causes which have retarded the civilisation of the African races. On the other hand, the deep fjords in, and chains of islands off, the coast of Norway have developed the seafaring habits of the people, and even now the mercantile marine of Norway is out of all proportion to the population. Fjords, however, though they make splendid harbours,

principally occur in cold regions where the land is bleak and high above sea-level, so that it cannot support a large population.

River-mouths do not generally make very convenient harbours; they are apt to get silted up, a bar forms across the mouth, and the sand-banks shift frequently and irregularly. Our lower valleys, however, were excavated at a time when, as we have already seen (ante, p. 105), the land stood at a higher level relatively to the sea, and the mouths have since been kept open by the action of the tides. It is partly due to the character of our coast and the excellence of our harbours, that "Britannia rules the waves."

CHAPTER V

THE ORIGIN OF MOUNTAINS

"In such scenes and with such accompaniments, the mind wanders from the real to the ideal, the larger and brighter lamps of heaven lead us to imagine that we have risen from the surface of our globe and are floating through the regions of space, and that the ceaseless murmur of the waters is the music of the spheres."

SIR JOSEPH HOOKER, *Himalayan Journals.*

THE true mountain ranges, that is to say the more elevated portions of the earth's surface, are the continents, on which most of the so-called mountain chains are mere wrinkles ; nevertheless, when we speak of mountains we generally mean those parts of the land which stand highest relatively to the water-level.

We are apt to think of mountains as rising to great heights, and in a sense so they do ; but when compared to the size of the earth itself, they are almost infinitesimal. In Fig. 51 the dark line gives the proportion of the highest mountains, and the section *abcd* that of a thickness of 100 miles in relation to the whole earth.

Mountains, in this sense, may be divided into two main[1] classes—

[1] I say main classes, because in certain cases there may be other explanations. Von Richthofen has suggested that the dolomites of the Tyrol were originally coral reefs.

1. Table mountains.
2. Folded mountains.

The highest points or peaks may again be divided into—

1. Mountains of denudation.
2. Volcanoes.

THE ORIGIN OF MOUNTAIN RANGES

The present temperature of the earth's surface is due to the sun, that supplied from the original heat of the planet being practically imperceptible. The variations of temperature due to seasons, etc., do not extend to a greater depth than about 5 feet. Beyond that we find as we descend into the earth that the heat increases on an average about 1° Fahr. for about every 60 feet.[1] Even, therefore, at comparatively moderate depths the heat must be very great. Many geologists in consequence have been, and are, of opinion that the main

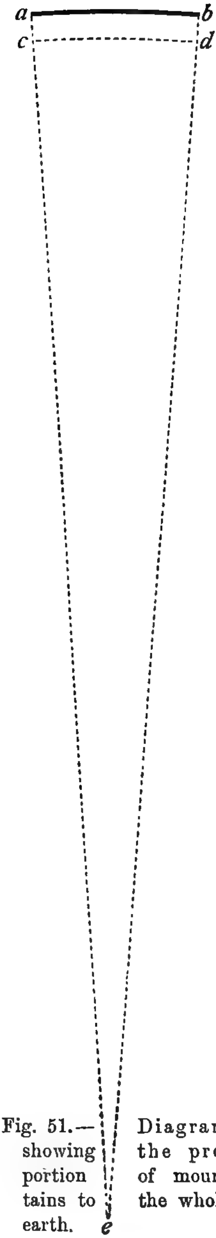


Fig. 51.—Diagram showing the proportion of mountains to the whole earth.

The dark line *ab* represents the present mountains; the segment *abcd* a thickness of 100 miles.

[1] The ratio, however, is subject to considerable variations. Mr. Henwood, who made the first observations on the subject, found that in the Cornish and Devon mines the rate of increase was even more rapid. On the other hand, Agassiz, in the case of the Calumet mine near Lake Superior, found a rate of 1° Fahr. for every 223 feet.

mass of the earth consists of molten matter. We know, however, that the temperature at which fusion takes place is raised by pressure, and it must not, of course, be assumed that the temperature continues to increase so rapidly beyond a certain depth. Other great authorities,[1] in fact, are of opinion that the mass of the earth, though intensely hot, is solid, with, probably, lakes of molten matter. In either case, as will be more fully explained on p. 180, the central mass continues slowly to cool and consequently to contract. The crust, however, remains at the same temperature and consequently of the same dimensions. This being so, under the overwhelming force of gravity one of two things must happen. Either (1), parts of the crust must break off and sink below the rest; or (2), the surface must throw itself into folds.

TABLE MOUNTAINS

Where the first alternative has happened, the parts which have not sunk, or which have sunk less than the rest, remain as tabular mountain masses, more or less carved into secondary hills and valleys by the action of rain and rivers. Such, for instance, is the Table Mountain of the Cape of Good Hope; its relative height is not due to upheaval, but to the surrounding districts having sunk. Indeed, as the earth is gradually contracting, we may say generally that the relative differences of level of land and sea are in the main due, not to elevation but to lowering,

[1] See, for instance, Lord Kelvin, *Lectures and Addresses*, vol. ii.

and this for three reasons: partly because the earth as a whole is contracting, partly because the formation of great ocean basins draws the water off the land, and partly on account of the enormous amount of denudation which has taken place.

FOLDED MOUNTAINS

Other mountains, however—those of Switzerland, for instance—belong to another class and have a very different character.

It used to be supposed that mountains were upheaved by volcanic action, by forces acting more or less vertically from below upwards, and the igneous rocks which occupy the centre of mountain ranges were confidently appealed to in support of this view. It must be confessed that when we first visit a mountainous region, this theory seems rational and indeed almost self-evident. It is now, however, generally admitted that such an explanation is untenable; that the igneous rocks were for the most part passive and not active; that, so far from having been the moving force which elevated the mountains, they have themselves been elevated, and that this took place long after their formation.

It might be, and indeed has been by some, supposed that the conglomerate and breccia of the Caradoc Sandstone series near Malvern were pushed up by the Syenite. Miss Phillips, however, long ago proved that this was not the case by observing that the breccia contains rounded and angular pieces of the

Syenite rock, which must therefore have been consolidated before the deposition of the Sandstone, and have been pushed up with it.

We may, indeed, lay it down as a general proposition that mountain chains are not due to volcanic action. When the two are associated, as in the Andes, the volcanoes are due to the folding and crushing, not the folding to the volcanoes.

As the crust of the earth cooled and solidified, certain portions "set," so to say, sooner than others; these form buttresses, as it were, against which the surrounding areas have been pressed by later movements. Such areas have been named by Suess "Horsts," a term which it may be useful to adopt, as we have no English equivalent. In some cases where compressed rocks have encountered the resistance of such a "horst," as in the north-west of Scotland and in Switzerland, they have been thrown into most extraordinary folds, and even thrust over one another for several miles.

Murchison long ago expressed his surprise at the existence of great plains such as those of Russia and Siberia. L. von Buch suggested as a possible explanation that they rested on solid masses which had cooled down early in the history of the planet, and thus had offered a successful resistance to the folds and fractures of later ages.

Mountains then have not been forced up from below, but thrown into folds by lateral pressure. This view was first suggested by De Saussure, worked out in fuller detail by E. De Beaumont, Sir Henry De la

Beche, in 1846, and recently developed by Ball, Suess, and especially by Heim.[1]

But whence arises the lateral pressure? Why are the surface strata thus thrown into folds? When an apple dries and shrivels in winter, the surface becomes covered with ridges. Or again, if we place some sheets of paper between two weights on a table, and then bring the weights nearer together, the paper will be crumpled up.

In the same way let us take a section of the

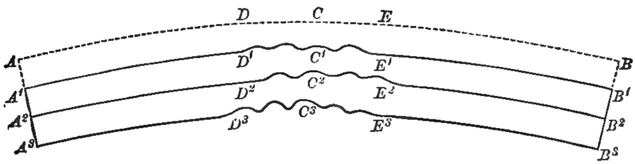


Fig. 52.—Diagram in explanation of Folded Mountains.

earth's surface (AB, Fig. 52) and suppose that, by the gradual cooling and consequent contraction of the mass, AB sinks to A^1B^1, then to A^2B^2, and finally to A^3B^3. Of course if the cooling of the surface and of the deeper portion were the same, then the strata between A and B would themselves contract, and might consequently still form a regular curve between A^3 and B^3. As a matter of fact, however, the strata at the surface of our globe have long since approached a constant temperature. Under these circumstances there would be no contraction of the strata between A and B corresponding to that in the interior, and consequently they could not lie flat between A^3 and B^3, but must be thrown into folds,

[1] See especially Heim's great work, *Untersuchungen ü. d. Mechanismus d. Gebirgsbildung.*

commencing along any line of least resistance. Sometimes, indeed, the strata are completely inverted, and in other cases they have been squeezed for miles out of their original position. "The great mountain ranges," says Sir A. Geikie, "may be looked upon as the crests of the great waves into which the crust of the earth has been thrown." Sir James Hall illustrated the origin of folds very simply (Fig. 53) by placing layers of cloth under a weight, and then compressing the two sides; and more complete experiments have since been made by Favre, Cadell, Daubrée, and Willis.

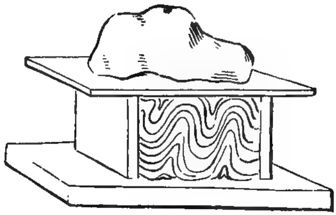


Fig. 53.—Hall's experiment illustrating Contortions.

Fig. 54 shows the result of one of Favre's experiments, in which he used the contraction of an indiarubber band to produce the folds.

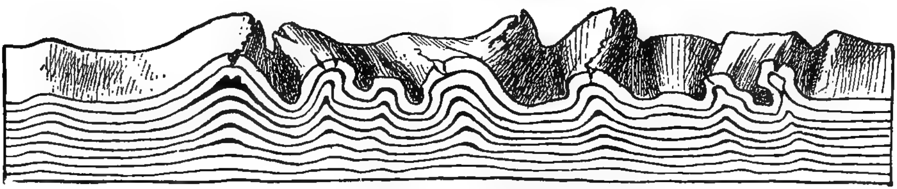


Fig. 54.—Showing the artificial folds produced in a series of layers of clay, on indiarubber, according to an experiment by Prof. A. Favre.

Mr. Mellard Reade indeed maintains[1] that the possible contraction due to this cause would be quite insufficient to explain the amount of folding. He suggests, however, that as the temperature increases,

[1] *The Origin of the Mountain Ranges*, 1886.

say, 1° Fahr. for every 60 feet (see ante, p. 176), the deposit of a mass of material, such for example as the Cambrian or Silurian strata, over any given area, would raise the temperature of the rocks which formed the previous surface, as well as that of the overlying sediments, and that the expansion, mainly lateral, arising from this increase of temperature must necessarily give rise to folding; and he points to the intimate association of mountain structure with great previous sedimentation in support of his theory of Mountain Building.

Lapworth has suggested a simple and instructive illustration[1] of the effect which folding must have on the strata concerned. Take an ordinary large notebook, say half an inch in thickness, with flexible covers. Rule carefully a series of parallel lines across the edges of the leaves at the top of the book, about $\frac{1}{8}$ of an inch apart, and at right angles to the plane of the cover. Then, holding the front edges loosely, press the book slowly from back to front into an S-like form until it can be pressed no farther. As the wave grows, the cross-lines which have been drawn on the upper edge of the book remain fairly parallel, except in the central third of the book, where they arrange themselves into a beautiful sheaf-like form, showing how much the leaves of the book have sheared or slidden over each other in this central portion. It will also be seen when the S is complete that the book has been forced into a third of its former breadth.

[1] Lapworth, *Brit. Ass. Rep.* 1892.

I have already (ante, p. 101) called attention to the fact that the folds are not single, but that there are two sets of lines in Great Britain crossing one another at right angles, the one running south-west to north-east, approximately along the line of the Caledonian Canal, and the other north-west to south-east.

This is no isolated case. A glance at the map will show that the Swiss rivers also follow two main lines at right angles to one another, and that these are again south-west by north-east, and north-west by south-east.

It may indeed be said that if we suppose a part of the earth's surface to be thrown up in the form of a fold, the drainage would naturally flow off the main axis and thus give rise to transverse rivers. Many valleys may no doubt be thus explained, but it is obvious that these would only be valleys of erosion. This explanation would not account for transverse folds or transverse faults.

The existence of two systems at right angles to one another is well marked in other mountainous regions. Darwin long ago called attention to it in South America.[1] Kjerulf has shown that parts of Norway are marked off in square blocks.[2] Professor Bonney[3] called attention to this tendency in his second lecture on the "Growth of the Alps." "On considering," he says, "the general disposition of the rocks constituting the Alpine chain, we perceive that, in addition to the long curving folds which determine the general

[1] *Geol. Observer*, 1857. See also Bertrand, *Bull. Soc. Geol. France*, 1892.
[2] De Lapparent, *Geogr. Phys.*
[3] *Alpine Journal*, Nov. 1888.

direction of the component ranges, they give indications of a cross folding."

Lapworth also refers to such intersecting folds in an interesting lecture on "The Pace of the Earth," but none of these authorities offered any explanation of the phenomenon, and Bonney agreed with Darwin that he found it impossible to explain the structure "by a single connected series of earth movements."

Under these circumstances I ventured,[1] in 1892,

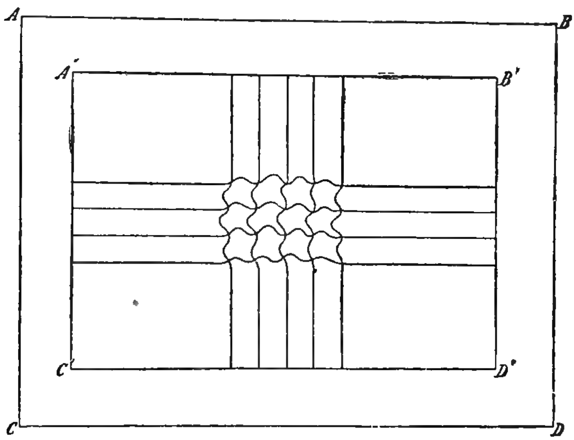


Fig. 55.—Diagram in illustration of Mountain Structure.

to make the following suggestion. If the elevation of mountains be due to cooling and contraction leading to subsidence, it seems evident, though, so far as I am aware, it had not then been pointed out, that the compression and consequent folding of the strata (Fig. 55) would not be in the direction of *AB* only, but also at right angles to it, in the direction *AC*, though the amount of folding might

[1] *Beauties of Nature*, 1892.

be much greater in one direction than in the other. Thus, as the main folds run south-west and north-east, the subsidiary ones would be north-west and south-east.

These considerations, then, seem to account for the two main directions of cross valleys which occur in so many mountainous regions, and suggest a reason for the sharp turns made by so many rivers.

Every mountain of this class begins as a gentle fold, and only attains its final form in the course of long ages. If we had been on the site of the Alps while they were rising, we should probably have been quite unconscious of the change which was going on, and which there is reason to think has not even yet ceased.

Each fold consists of an arch and a trough, between which is a middle limb; and as the process of folding progresses, the middle limb yields, and the arch is folded gradually over the trough, until at last all three come into contact, and form a solid mass, when any further folding is impossible. As Lapworth says, "the fold is dead, though, if the earth-pressure increases, the material which has been thus packed together may, of course, form a passive part of a later fold, but the first folds themselves can relatively move no more."

The final result, then, is to strengthen and consolidate that part of the earth's surface which at first was weakest. If, therefore, the lateral pressure is continued, the next fold will probably commence at the side of, and parallel to, the first.

Hence it very seldom happens that only a single fold is produced. If the pressure continues, the resistance generally becomes weaker either on one side or both of the primary fold, than along the primary fold itself, and a new fold is formed on one side or both, parallel to the first. If only one is produced, we have such a case as the Jura, with a main arch and a series of minor folds on one side. If there are new folds on both sides, we have a bilateral range, like the Alps, with a main central fold showing the characteristic fan structure of mountain chains, buttressed as it were by minor folds on each side.

In one part of the South Staffordshire coal-field the same bed of coal was passed through three times in the same vertical shaft, first in its right position, then inverted, and thirdly, right side uppermost: it must, accordingly, have been bent into the shape of the letter S.

The very same movement may give rise to an elevation in one place, a depression in another, and leave a third unchanged. Suppose, for instance, any rod, say a pencil, held at the centre, and which is being raised at one end and depressed at the other. The middle remains at the same level, but one side is raised and the other depressed. If such a fulcrum is at or near a coast, though the land may be rising or the sea-bottom sinking, the shore would show no apparent change. If, on the other hand, the fulcrum was to the landward the rotation would lower the shore, while if the fulcrum was under the sea the same movement would raise it. Thus there may be

many apparent differences, while in reality the movement remains the same.

The edges of strata which appear at the surface of

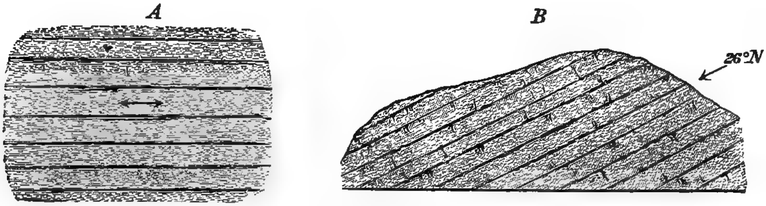


Fig. 56.—Diagrams showing (A) the Strike, and (B) the Dip of strata.

the ground are termed their "outcrop." Sometimes they are horizontal, but if not the slope is called their "dip" (Fig. 56). A horizontal line drawn at a right

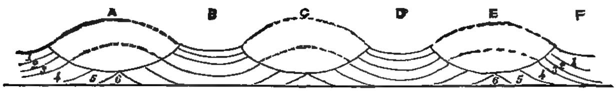


Fig. 57.—Diagram showing Anticlinal and Synclinal Folds.

angle to the dip is termed the "strike" (Fig. 56). If we imagine a layer of rock bent up into an arch like the roof of a house, the ridge would be the strike, and the slope the dip.

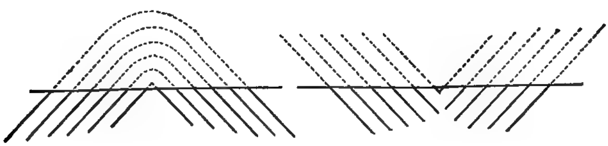


Fig. 58.—Razed Folds.

Where strata are thrown into such folds the convex portion is termed an anticline (Fig. 57, A, C, and E) and the concave a syncline (Fig. 57, B, D, and F). The same terms are applicable when the surface has been planed down so that the strata would dip as in Fig. 58.

The inner strata of any fold are called the core,

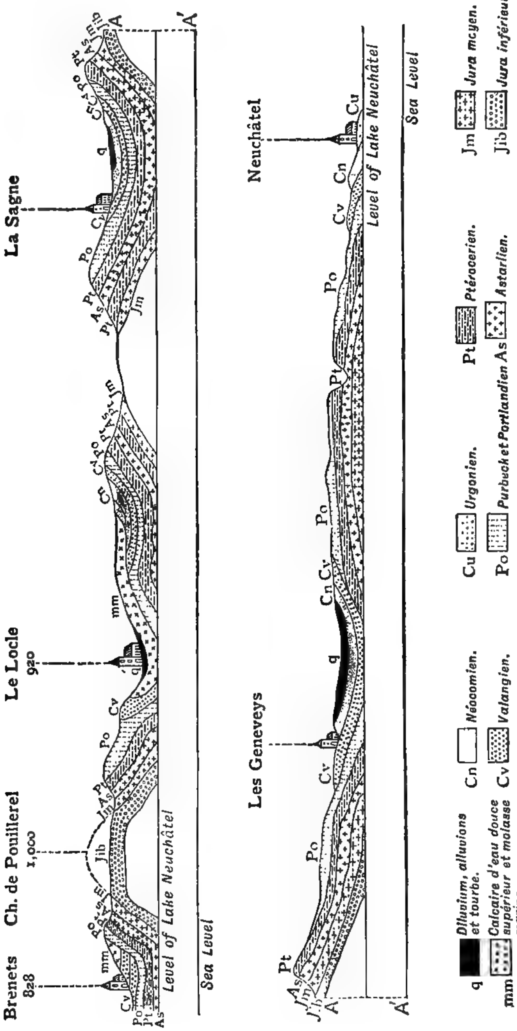


Fig. 59.—Section across the Jura from Brenets to Neuchâtel.

those of an anticline (Fig. 57, A) being called the arch core, those of a syncline (Fig. 57, B) the trough core.

There is perhaps no district where they are better shown than in the Jura. A glance at any good map of that district will show a succession of ridges running parallel to one another in a slightly curved line from south-west to north-east. That these ridges are due to folds of the earth's surface is clear from the foregoing figure (Fig. 59) from Jaccard's work on the Geology of the Jura, showing a section from Brenets due south to Neuchâtel by Le Locle. These folds are comparatively slight and the hills of no great height.

The Thames valley from Reading to the sea is a synclinal depression (see Fig. 21, p. 97).

It is obvious, of course, that when strata are thrown into such folds, they will, if strained too much, give way at the summit. Before doing so, however, they are stretched and consequently loosened, while, on the other hand, the strata at the bottom of the fold are compressed; the former, therefore, are rendered more susceptible of disintegration; the latter, on the contrary, acquire greater powers of resistance, and the result is that any joints or cracks are opened and widened in the anticline, compressed and closed in the syncline.

The diagram (Fig. 57, p. 187) represents six strata (1-6), supposed to be originally of approximately equal hardness, but which, after being thrown into undulations, are rendered more compact in the hollows and less so in the ridges. Denudation will then act more effectively at A, C, E than at B, D, F, and when it has acted long enough the surface will be shown by the stronger line. This will be still more

rapidly the case if some of the strata are softer than others. Where they are brought up to the surface erosion will, of course, act with special effect. Hence it often happens that hills have become valleys, and what were at first the valleys have become mountain-tops. As an illustration I give a section in the Lake District (Fig. 60) from Ling Fell to Newlands Beck.

Again, in North Wales,[1] in Yorkshire,[2] and indeed generally, the anticlines form valleys, the synclines hills.

When we look at these abrupt folds and complicated contortions, the first impression is that they must have been produced before the rocks had solidified. This, however, is not so. They could not indeed have been formed except under pressure. We must remember that these rocks, though they are now at or near the surface, must have been once at a great depth, and where the pressure would be tremendous. Even in tunnels, which of course are but

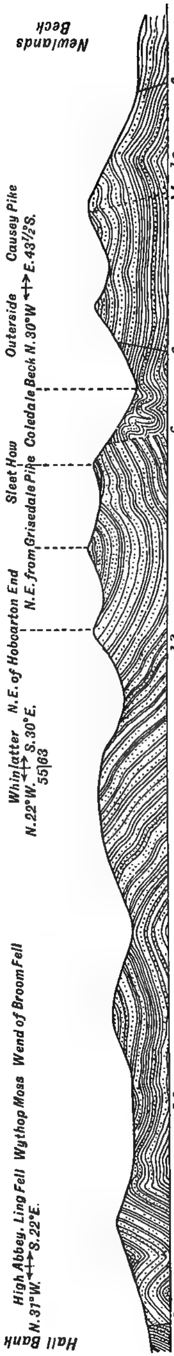


Fig. 60.—Section in the Lake District from Ling Fell by Grisedale Pike to Newlands Beck. *fff*, Faults; *b*², volcanic series; V, a vein.

[1] *Mem. Geol. Surv.*, N. Wales.
[2] Davis and Lees, *West Yorkshire.*

little below the surface, it is sometimes found necessary to strengthen and support the walls, which would otherwise be crushed in. The roadways in coal-mines are often forced up, especially where two passages meet. This indeed is so common that it is known as the "creeps." In deep tunnels it has not unfrequently happened that when strata have been uncovered they have suddenly bent and cracked, which shows that they were under great lateral pressure. Yet the deepest mine scarcely reaches 5000 feet.

Tresca[1] has shown by direct experiment that the most solid bodies, lead, tin, silver, copper, and even steel, will give way and "flow" under a pressure of 50,000 kilograms per square centimetre. In fact, rocks which have not attained a certain solidity could not be folded. Moreover, there is direct and conclusive evidence that the Swiss rocks were folded after solidification. In many cases contorted rocks contain veins (Fig. 64, p. 195), which are really cracks filled up with calcite, etc. Such fine fissures, however, can only occur in hard rock. Again, the Lower Tertiary rocks contain rolled pebbles of gneiss, Jurassic rocks, etc., which must therefore have become hard and firm before the Eocene period,[2] while the folding did not occur till afterwards. It is clear, therefore, that when the folding took place the rocks were already solidified. No doubt, however, the folding was a very slow process. Whenever we find

[1] *Comptes Rendus*, vol. lxxviii. 1874.
[2] Heim, *Mech. d. Gebirgsb.* vol. ii.

a fold we may be sure that, when formed, it was deep down, far below the surface, under enormous pressure, and where the material was perhaps rendered somewhat more plastic by heat. In the later and

Fig. 61.—Hand specimen of contorted Mica Schist.

upper rocks we find compression with fracture, in the earlier and lower rocks compression with folding.

Folds and fractures are indeed the two means by which the interior strains adjust themselves. They replace one another, and in the marvellously folded districts of the Alps faults are comparatively few, though it must not be supposed that they do not occur. The nature of the rock has little influence

on the great primary folds, but the character of the minor secondary folds depends much upon it.

Fig. 61 represents a piece of contorted Mica Schist, and it will be seen that the folds are a miniature of those to which on a great scale our mountains are due.

These earth movements have given rise to fractures, and strata are frequently divided by intersecting joints, often at right angles and crossed by a third

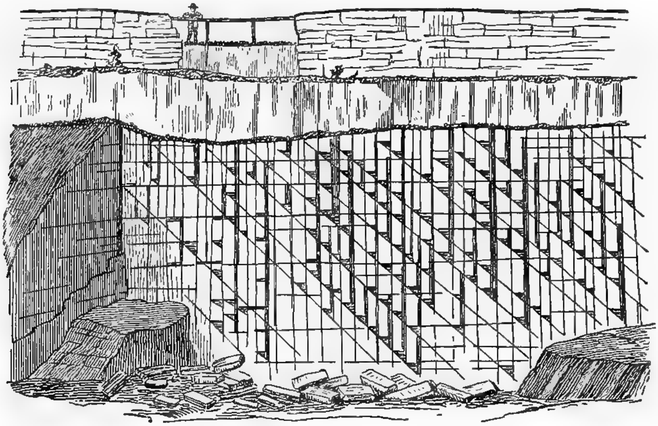


Fig. 62.—Face of Quarry in Carboniferous Limestone at Ballinure, near Blackrock, County Cork, looking south.

series at an angle of 45° (Fig. 62), as, for instance, in the above figure representing a quarry of Carboniferous Limestone at Ballinure, County Cork. These crossing joints greatly contribute to the destruction and removal of rocks.

In many cases the rock is broken up into flat or more or less lenticular pieces, which have been squeezed over one another so that their surfaces have been rendered smooth and glistening (Fig. 63). Such surfaces are known as slickensides.

This process has sometimes been so intense and so general that hardly a piece can be found which does not present such a polished surface. The particles of stone which now touch were once far apart, others which are now at a distance once lay close together.

The cracks, movements, and friction which result

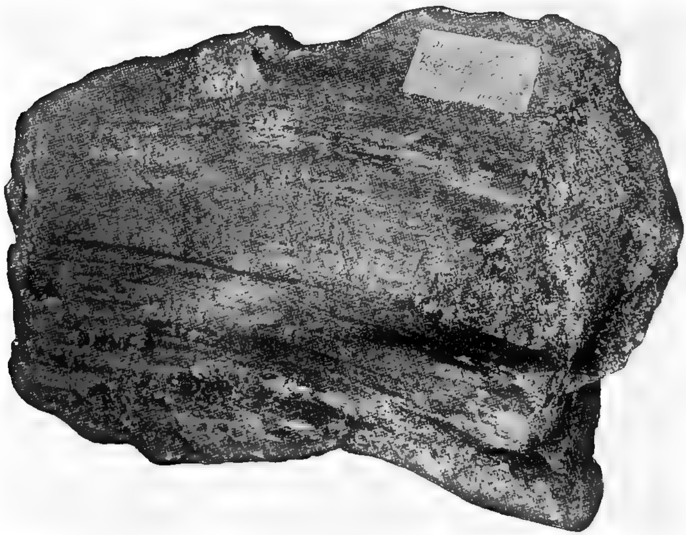


Fig. 63.—Piece of Millstone Grit, from the Peak, Derbyshire, showing slickensides.

in such a structure must from time to time produce sounds, and the mysterious subterranean noises sometimes heard are perhaps thus produced.

Fig. 64 represents a section of Rothidolomite, and it will be observed that, as we should expect theoretically, the strata are thinner in the limbs, where they are squeezed out, and broader in the arches. This is visible in great mountain folds, as well as in hand specimens.

In the part of the curve where the effect of the force is to draw out the strata, they will, as shown above, if capable of giving way, become thinner.

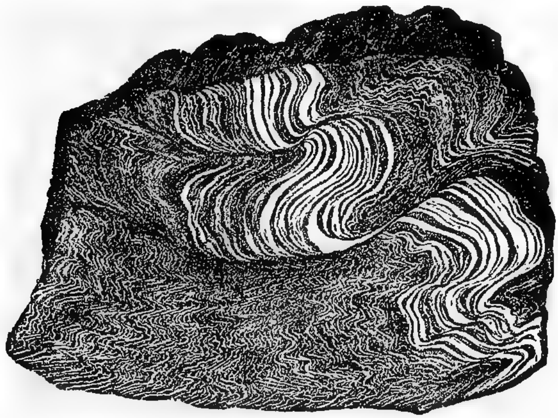


Fig. 64.—Section of Rothidolomite.

If, however, they are not plastic they must crack, the combined width of the cracks affording the additional space. Fig. 65 represents a fragment of rock which has been thus drawn out.

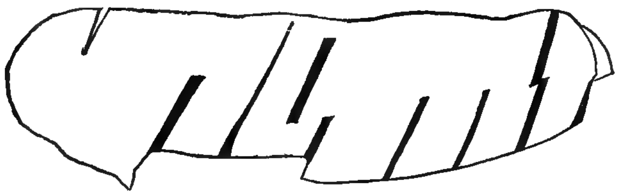


Fig. 65.—Piece of stretched Verrucano.

It is obvious that before strata could be thrown into contortions such as those in Figs. 71-75, they must have been subjected to tremendous pressure. They have consequently been much altered, and the fossils compressed, contorted, crushed, ground, and

partly or in many cases completely obliterated. Fig. 66 represents Belemnites thus torn; in these cases the extension or tearing is due, not to a general extension of the rock, but to lateral thrust.

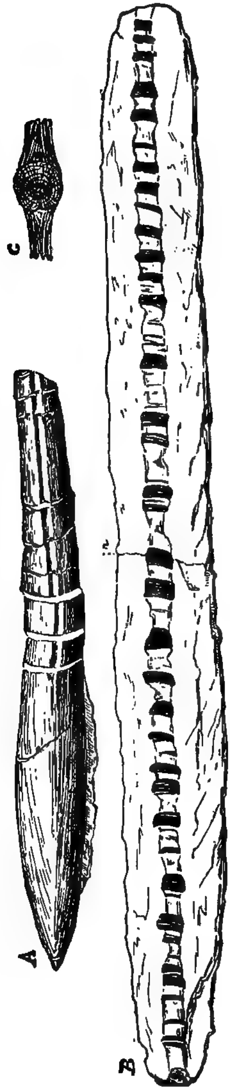


Fig. 66.—Stretched and broken Belemnites, ½-size. *A*, Belemnites hastilis, slightly broken, Frête de Saille; *B*, Specimen much drawn out; *C*, Section at *n*.

Fig. 67 represents a fragment of nummulitic Limestone in which the rock has not only been fractured along the piece *ab*, but one side of the vein has been evidently displaced. At a later date another fracture has taken place along the line *cd*.

In many cases the pressure has produced "cleavage" or

Fig. 67.—Fragment of Nummulitic Limestone.

"foliation," and turned the rocks into slate,[1] so that they split into more or less perfect

[1] English geologists apply the term "shale" to rocks which split along the laminæ of original deposition, and which are comparatively soft and

plates or films. The direction of cleavage is quite independent of the stratification, which it may cross at any angle. It is due to pressure, the minute particles in the rock being flattened by, and arranged at right angles to, the pressure, as shown in Figs. 68 and 69.[1]

The fact that cleavage has been produced by pressure was first demonstrated by Sharpe, and afterwards with additional evidence by Sorby and Tyndall.

Fig. 68.—Section of a fragment of Argillaceous Rock.

Fig. 69.—Section of a similar Rock which has been compressed, and in which cleavage structure has been developed.

Cleavage and folding are both due to the same cause. They have arisen simultaneously, and are different manifestations of the same mechanical action.

In some cases a second and subsequent cleavage

destructible, and "slate" to those where the lamination is due to cleavage. Continental geologists generally include shales and slates under the same name.

[1] Sir A. Geikie, *Text-book of Geology*.

has occurred in a more or less different plane, but such cases are not frequent.

"Foliation" may have been produced in several ways, but, speaking generally, it may be defined as a rearrangement of the materials by chemical action, while cleavage is due to pressure.

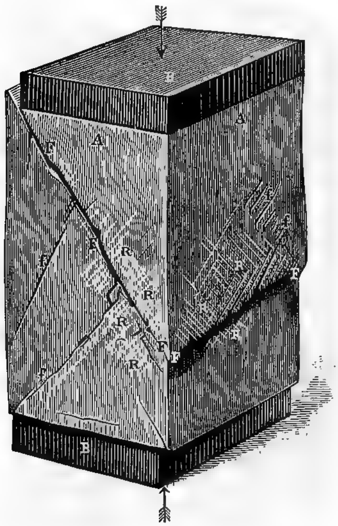


Fig. 70.—Prism of Sealing-wax submitted to the action of a hydraulic press in a vertical direction. BB, iron plates of the same section as the prism; FF, principal fracture showing line of movement; *ff*, cracks at right angles to the preceding; RR, network of fine, nearly rectangular, fissures developed on the bulging parts of the four sides of the prism. Scale ⅕.

M. Daubrée[1] subjected a block of sealing-wax to the action of the hydraulic press in the direction of the arrows. A fracture FF soon took place obliquely to the pressure, at an angle of about 45°. This crack gradually extended right across the block, and it showed slight undulations and alternations of width very much resembling those of metallic veins. Two other cracks soon made their appearance, nearly, but not quite, at right angles to the first.

Besides these principal fractures there were, especially on certain parts, many parallel lines (RR) of fissures in two series at right angles to one another,

[1] *Géol. Expérimentale.*

and parallel respectively to the two principal fractures. They formed a tissue of closed meshes, and though fine were very distinct. The mass had also developed an incipient cleavage.

It is unnecessary to point out how closely these fractures correspond to those which occur in many rocks.

But in spite of these theoretical considerations

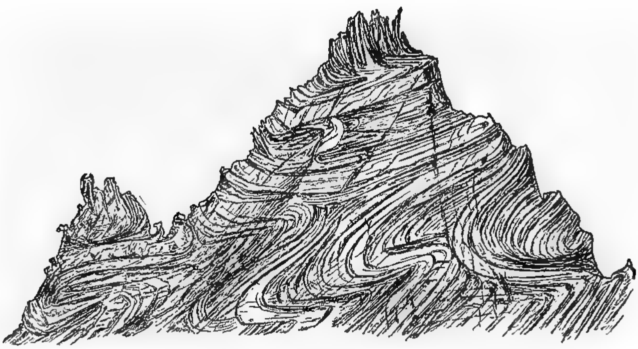


Fig. 71.—Section of upper part of the Faldum Rothhorn.

and the evidence of hand specimens, so enormous must be the force required to throw the surface of the earth into these great folds, that it would be difficult to realise the possibility if the strata were not there to speak for themselves.

Fig. 71 and the following figures give an idea of the remarkable folds and crumpling which the strata have undergone. One of the most remarkable is shown by the Faldum Rothhorn in Switzerland (Fig. 71), where the strata have been compared to a handful of ribbons thrown on to the ground.

Fig. 72 is a photograph of the Cascade of Arpenaz

in the valley of the Arve. It shows a grand arch, but

Fig. 72.—Cascade of Arpenaz.

unfortunately the figure does not include the whole fold, which takes the form of an S, the middle part of which only is shown in the photograph.

Fig. 73.—Lulworth Cove.

Figs. 73 and 28 (p. 122) show some remarkable contortions in Chalk near Lulworth, Fig. 74 in the

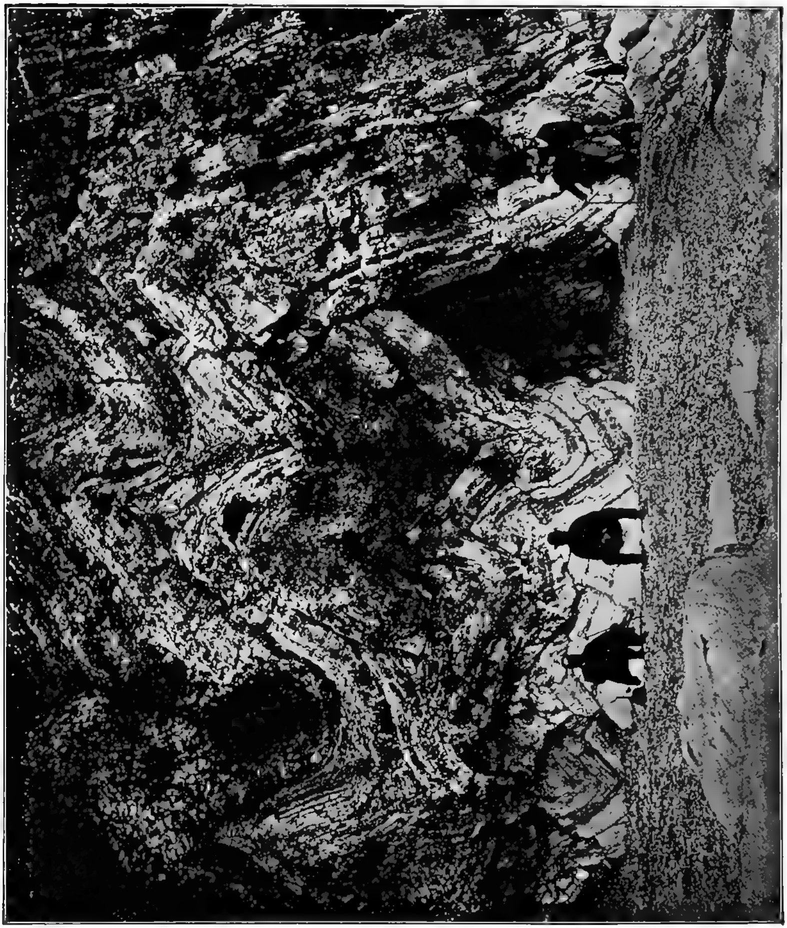


Fig. 74.—Contortions in Chalk, Staple Nook, Flamborough Head.

Chalk cliffs of Flamborough Head, and Fig. 75 in Carboniferous Limestone near Skipton in Yorkshire.

The configuration of the surface has been so much modified by denudation that these folds do not

affect the present arrangement of hills and valleys so much as might have been expected.

Fig. 75.—Contortions in Carboniferous Limestone, Skipton, Yorkshire.

Where strata have been bent, as in Fig. 76, they are said to form a monoclinal fold.

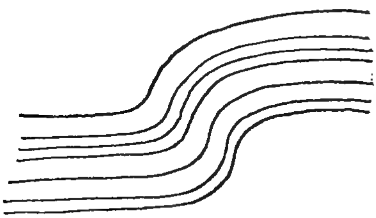


Fig. 76.—Monoclinal Fold.

Fig. 77.—An Inclined Fold.

When an arch, instead of being upright, is thrust to one side, it is said to be inclined or recumbent (Fig. 77).

FAULTS.

Where the subterranean forces have ruptured the strata and pushed one side of the crack more or less upwards or downwards (Fig. 78), the fracture is termed a fault.

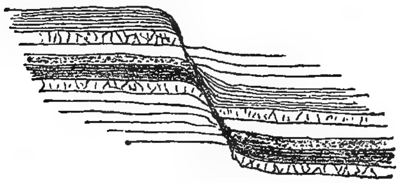


Fig. 78.—A Fault.

In Fig. 78 the strata were already slightly bent before the fracture. When this is more accentuated we have a fold-fault (Fig. 79).

Faults may be small, and the difference of height between the two sides only a fraction of an inch; or, on the other hand, they may range to several thousand feet. Fig. 80 is a photograph (half nat. size) of a block of stone from Coniston Old Man. So far as the bulk of the stone is concerned it would be difficult to detect any fractures. It is, however, ruled, as it were, by fine lines of a darker substance, and these clearly show that it has been fractured in many places, and that the pieces have in several places been moved relatively to one another. In this case the dislocations were very small. On the other hand, some faults are

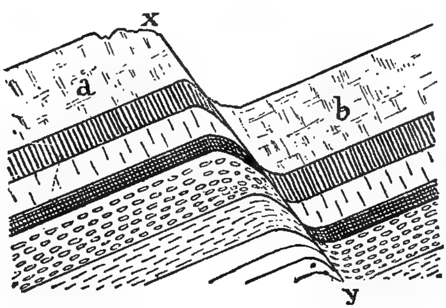


Fig. 79.—A Fold-fault. Line of fault (x y) at the upper displaced bed. The beds are bent near the fault by the strain before the actual fracture took place.

immense. In the case of one great fault described by Ramsay, the difference is no less than 20,000 feet, and yet so enormous has been the denudation that the surface shows no indication of the existence of the fault, and one may stand with a foot on each side, unconscious of the fact that the stratum under the one represents a geological horizon so much above that under the other.

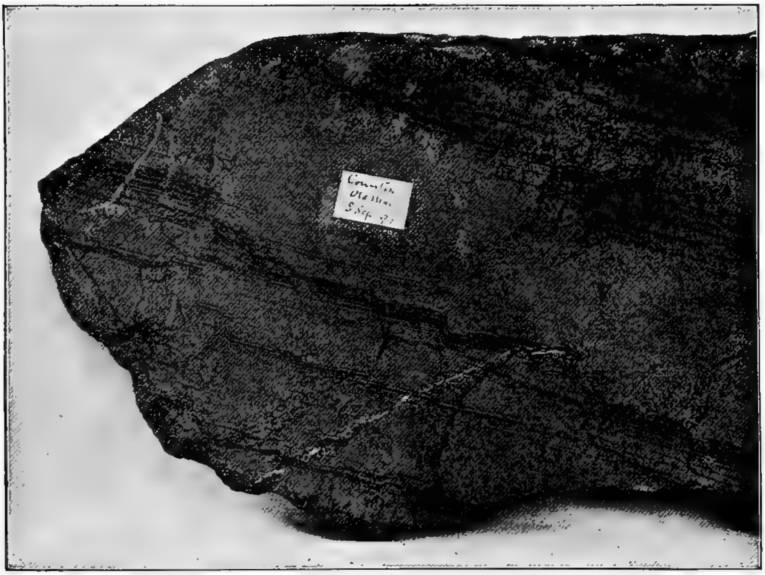


Fig. 80.—Block of Stone from Coniston Old Man. ½-size.

Many parts of the country are intersected by innumerable faults, some of great magnitude.

On Sheet 19 of the Geological Survey Map (1 inch to the mile) no less than 160 faults are represented, and there are in reality many more, as of course the principal ones only could be shown. North Wales is much faulted. The Great Bala fault extends from the coast at Dysynni, north of the

mouth of the River Dovey, and extends to the north-east near Tal-y-Llyn and Moel Ddu, along the Bala Lake into Cheshire. The downthrow is to the north-west. Ramsay estimates it between Mynydd Ceiswyn and Geu-Graig at 1000 feet, farther to the north-east near Pen-bryn-fforchog at 6000, near Aran Mowddwy at from 10,000 to 11,000, while at the Bala Lake it is reduced to from 5000 to 6000.

Another great fault runs from Dinlle in Carnarvon north-west, parallel to the Menai Straits, to the mouth of the Aber, above which it is cut off by another fault at right angles to it, running up the valley of the river. It bounds the Cambrian rocks of Llanberis for about 14 miles, throwing down Silurian slaty shales from 2000 to 3000 feet on the north-west against the Cambrian strata.[1] Another, following the same direction, from Carnarvon to Bangor, brings unaltered limestone, conglomerates, sandstones, and shales of Carboniferous age against the porphyry and Cambrian rocks. In this case also the downthrow is on the north-west.

Many of the greater Welsh faults run parallel to the Menai Straits, but there are numerous and generally shorter ones in other directions. They generally take a fairly straight course, but not invariably. One, for instance,[2] between Llyn Peris and Dinas attempts, as it were, a sharp curve. Round Snowdon itself there is a perfect network of faults. The lower part of the Pass of Llanberis runs along a line of fracture.

[1] *Mem. Geol. Surv.* vol. iii. North Wales. [2] *Ibid.*

The Pennine range is due to a sharp fold, which passes into two complicated and important series of faults, running N.N.E. by S.S.W. They are not continuous for any great distance, but divide from time to time into more or less parallel branches. They commence in the South of Scotland, and run by Brough in Westmoreland to near Kirkby Lonsdale, then west of Ingleborough to Clapham, then make a sweep round Austwick to Feizer, and so to the grand escarpment from Giggleswick to Settle.

The maximum throw is estimated at from 6000 to 7000 feet, and Carboniferous or even Cambrian rocks on the east are brought up against Permian strata on the west.[1]

These faults are crossed by another series approximately at right angles to the first.

The presence of faults is rarely indicated at the surface, unless indeed rocks of different degrees of hardness are brought together, in which case the projecting rock is not that which has been relatively raised, but that which is most durable.

This is the case, for instance, with the fault (Fig. 81) between Giggleswick and Settle known as Giggleswick Scar. The high ground to the left of the photograph is Carboniferous Limestone, and the low ground on the right is Millstone Grit. This is one of the few cases in Great Britain where a fault influences the surface features of the ground. The effect, however, is indirect, and is due to the fact

[1] Woodward, *Geol. of England and Wales;* Davis and Lees, *West Yorkshire.*

Fig. 81.—Fault between Giggleswick and Settle.

that the fault has brought the more destructible Millstone Grit against the less destructible Carboniferous Limestone. It will be remembered that the Carboniferous Limestone is older than, and underlies, the Millstone Grit. Originally, of course, the latter extended over the Carboniferous Limestone to the left of the figure, and has been removed by denudation.

In some cases the strata have been folded and even inverted, so that the more ancient lie over the more recent beds in inverse order, as, for instance, at Malvern[1] and in the Abberley Hills,[2] where the Lower Ludlow strata have been inverted over the Upper. Sedgwick regarded some of the Devonian slates of Cornwall as being inverted. In other cases the strata have been pushed over one another, forming what are known as "overthrusts."

A remarkable case in the Isle of Purbeck is exhibited in Fig. 82. Sir A. Geikie also mentions one on the foreshore at Eastbourne.

Fig. 83 is a view of Durdle Cove, with Swyre Head in the centre and Bat's Head to the left. The rock quite to the right is Upper Greensand, the rest Chalk. The slide-plane has enabled the sea to hollow out the series of little caves.[3] The indications on the tissue-paper will, I hope, make the figure clear.

The Scotch Highlands, however, present even more remarkable examples.

[1] Horner, *Trans. Geol. Soc.* 1st ser. vol. i. 1811; and Groom, *Quar. Jour. Geol. Soc.* vol. lv. 1899.

[2] Phillips, *Geol. Sur. Mem.* vol. ii. 1848.

[3] *Proc. Geol. Ass.* vol. xvii. 1901.

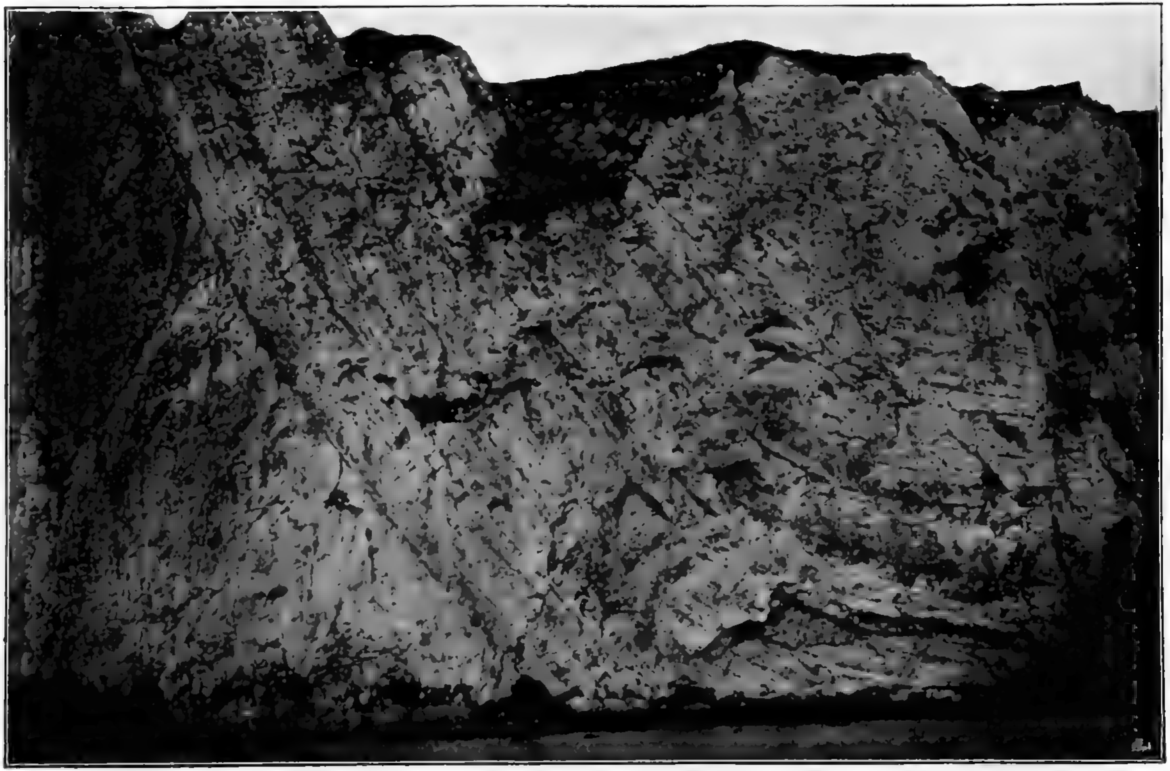
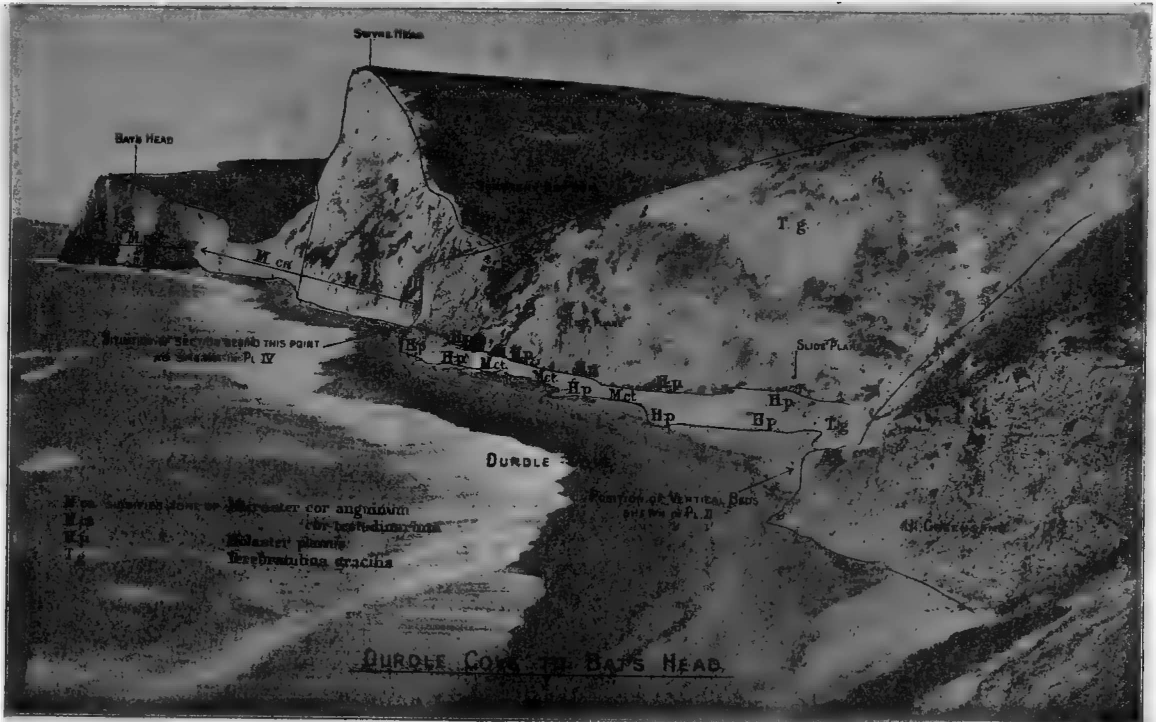


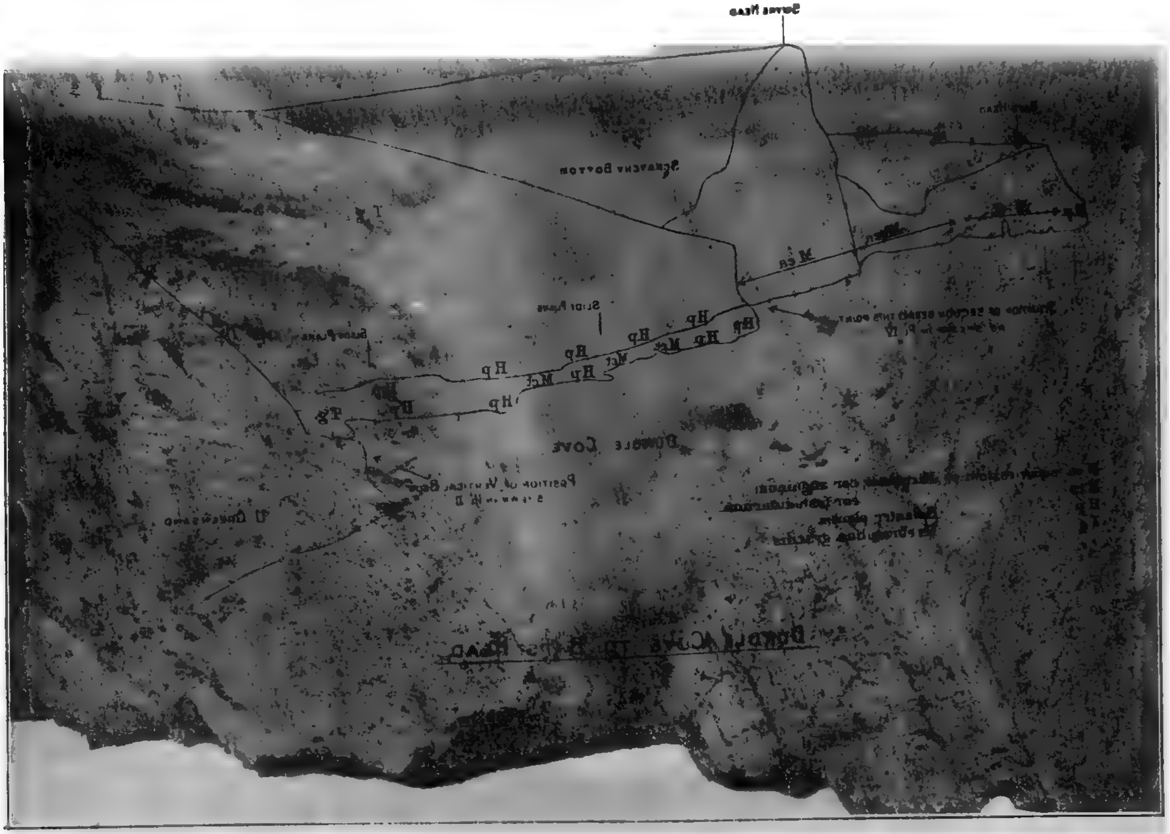
Fig. 82.—Overthrust, Isle of Purbeck.

Bat's Head. Swyre Head. Scratchy Bottom.



Chalk. Greensand.

Fig. 83.—Durdle Bay, looking West to Bat's Head.



Swyre Head
Scratchy Bottom

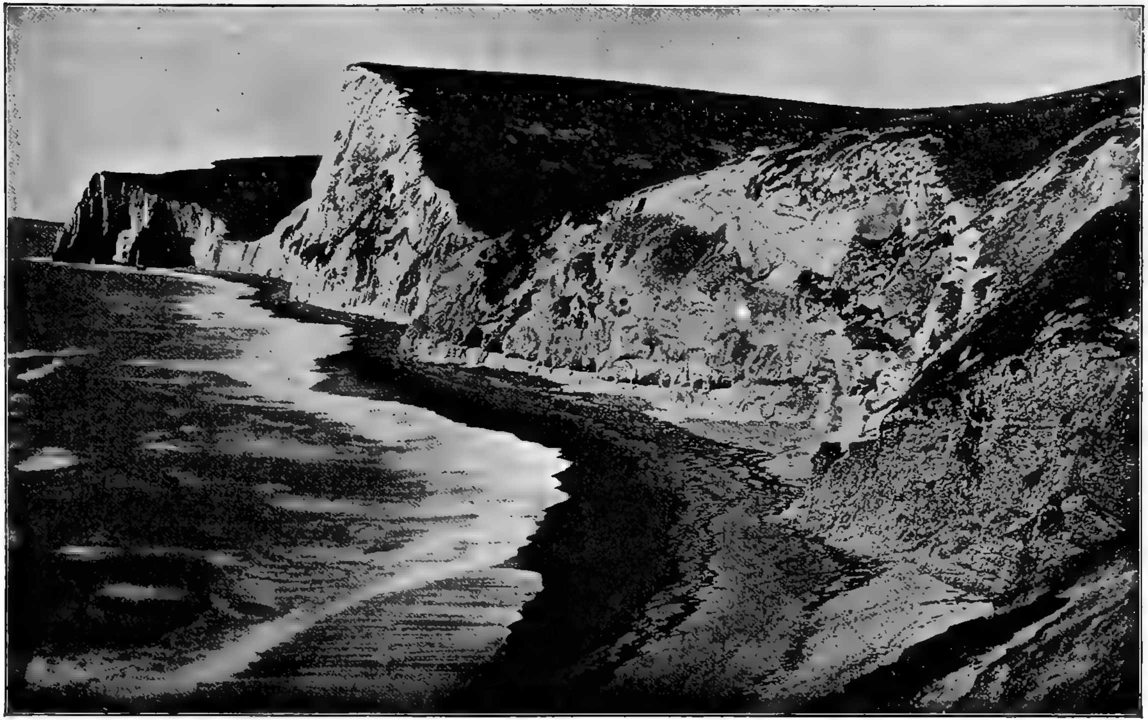


Fig. 83.—Durdle Bay, looking West to Bat's Head.

Besides these great overthrusts there is another type of relative earth movement which is known as a "lag fault." The Lake District affords us a typical case. Since Ward wrote his admirable Memoir our knowledge of earth-movements has made considerable progress. Harker and Marr have suggested that the folding and faulting which have affected the Lower Palæozoic rocks of the district are primarily due to the pushing forward of the rocks in a general northerly direction by a force acting from the south.

Further, that the rocks moved forward at unequal rates, and that as far as the main mass of rocks now exposed is concerned, the Skiddaw Slates moved farthest forward, the Green Slates and Porphyries lagging behind, and the Upper Slates in turn remaining behind the Green Slates and Porphyries.

As the result of the lagging, they believe that a fault with a fissure approaching the horizontal was formed between the Skiddaw Slates and the Green Slates and Porphyries, and a similar fissure between these volcanic rocks and the Upper Slates.

CHAPTER VI

THE ORIGIN OF MOUNTAINS—(*continued*)

"Le profil de l'horizon affecte toutes formes ; aiguilles, faîtes, créneaux, pyramides, obélisques, dents, crocs, pinces, cornes, coupoles ; la dentelure s'infléchit, se redresse, se tord, s'aiguise de mille façons, mais dans le style angulaire des sierras. Les massifs inférieurs et sécondaires présentent seuls des croupes arrondies des lignes fuyantes et courbes."—AMIEL.

MOUNTAIN TOPS

HAVING in the previous chapter dealt briefly with mountain districts and mountain chains, we will now consider the origin of mountain summits.

These may be classed in two divisions—

1. Volcanoes.
2. Mountains of denudation.

Our English mountains belong to the latter class, although, as we shall see, the volcanoes of former ages have profoundly influenced our scenery.

While the primary configuration of the country's surface is no doubt due to tectonic causes, the present surface is mainly the result of denudation. Our mountains, even the loftiest, are not parts of the

earth's surface which have been raised highest but those which have been lowered least. The summit of Snowdon, the highest of all, was once the bottom of a valley (Fig. 96, p. 256). As a rule, we may say that the harder the rock the higher the ground. The tough volcanic rocks of the Lake District and North Wales stand generally at a higher level than the Carboniferous Limestone of Derbyshire; the Carboniferous Limestone districts are, on the whole, higher than the Oolites or the Chalk; the Oolites and the Chalk than the softer sands and gravels of Central and Southern England.

Hence it is that in most mountainous districts so many of the peaks stand at about the same level. Every one who has ever enjoyed the view from the top of a mountain must have observed that the valleys seem much less important than they do from below. They show themselves to be in many cases mere "nicks" cut into the high ground.

Let us imagine a country raised above the water with a gradual and uniform slope towards the sea. Rivers would soon establish themselves, guided by any inequalities of the surface, and running, in the first instance, at more or less equal intervals down to the water-level. They would form valleys, down the sides of which secondary rivulets would flow into the main streams. The rain and frost would denude with especial rapidity those parts of the surface which offered the least effective resistance, and thus not only would the original watershed be cut into detached summits, but secondary ridges would be

formed approximately at right angles, to be again cut into detached summits like the first.

The primary watershed is of course higher than the secondary watershed, and the secondary watershed gradually slopes away from the primary. Hence the peaks on the secondary watershed will gradually diminish in height as they recede from the primary. On the ridge between the Val d'Herens and the Val d'Anniviers in the Valais, we have the following succession, passing from south to north—Dent Blanche, 4364 metres; Grand Cornier, 3969; Bouquetin, 3484; Pigne de l'Allée, 3404; and Garde de Bordon, 3316.[1]

From the agency of frost and the tendency of many rocks to split up in three different directions (Fig. 62, p. 193), rocks often break into cubical masses. Rain and wind then remove the finer particles; hence we often find that the tops of mountains are assemblages of rock masses (Fig. 84), giving the impression as if they had been thrown together by giants.

The very presence of granite or gneiss on the surface implies immense denudation (see ante, p. 3), and the same may be said of slaty rocks, for if they had been near the surface the pressure would have crushed them upwards.

The importance of denudation was first realised by Hutton in 1795, who stated the main facts in terms which cannot even now be improved; and by Scrope, who applied the theory in a masterly manner to the district of Auvergne; Farey appears to have been the first who applied the word in its present sense.

[1] Marr, *Scientific Study of Scenery.*

The general opinion of geologists used, however, to be, in the words of Sir R. Murchison, that "most of the numerous deep openings and depressions which exist in all lofty mountains were primarily due to cracks which took place during the various movements which each chain has undergone at various periods."

No doubt there are such cases, but the principal

Fig. 84.—Summit of a Lateral Hill on Coniston Old Man.

instances which were relied on are now proved to have been gradually cut down by running water, as, for instance, the gorge of the Avon at Clifton, that at Cheddar, etc.

The rapidity of denudation is, of course, affected greatly by the character of the strata, so that the present level depends partly on the original configuration, partly on the relative destructibility of the rock.

Baked by the sun, fractured by frost, the rocks

are broken up by degrees; in dry weather the surface crumbles to powder, and the finer particles are blown away by wind, while at the first storm the rain runs off as a muddy torrent which sweeps the mud, sand, and gravel down to the nearest brook, and the surface materials slowly but surely creep and slip down the hillsides.

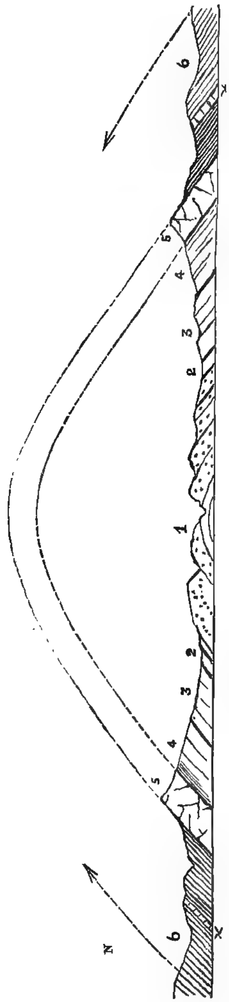


Fig. 85.—Section across the Cambrian and Lower Silurian rocks of Merionethshire. 1, Harlech Grits; 2, Menevian Beds; 3, Lingula Flags; 4, Tremadoc and Arenig Slates; 5, Igneous series; 6, Llandeilo and Bala Beds; *x*, Bala Limestone.

Under these influences the general surface is gradually lowered, and how enormous the denudation must have been in the lapse of ages is well shown, for instance, in the section, after Ramsay (Fig. 85), across the Cambrian and Lower Silurian rocks of Merionethshire. It is obvious that the Bala Beds (No. 6) on the right-hand side of the figure were continuous with those on the left, and must have formed a great dome. The Weald (Fig. 106, p. 278) is a similar case. The Peak of Derbyshire (Fig. 102, p. 269) is due to a fragment of Millstone Grit still remaining, while the surrounding portions have been washed away. Whernside, Ingleborough, and Penyghent (Fig. 102, p. 268) are also

masses of Millstone Grit standing on a plateau of Carboniferous Limestone, and once formed part of a continuous mass.

It will be observed in Fig. 85 that the stratum No. 5 (Igneous rock) projects beyond those on either side, obviously because it is harder. Such ridges are known in Central England as edges (Wenlock Edge, Alderley Edge, Axe Edge, Bamford Edge, etc.), and are termed in geology "escarpments." The Pennines, Cotteswolds, and Chilterns are such escarpments.

"An escarpment," says Whitaker, "may be defined as the bounding ridge of a formation or bed, that is to say, the ridge along which a formation or bed is cut off, and beyond which it does not extend, except in the form of outliers; it follows the line of strike."

Escarpments present a general resemblance to, and were formerly taken for, sea cliffs. They differ, however, essentially, as Whitaker has well shown.[1] If the Chalk escarpment, for instance, were a sea cliff, it must not only resemble a coast, but a Chalk coast. It presents, indeed, some resemblance to a coast which consists of harder and softer rocks, and hence presents bays and headlands; but a Chalk coast presents a fairly straight line, while a Chalk escarpment is much indented by coombes and valleys. Again, the shore-line must follow the sea-level, but the base of Chalk escarpments often rises and falls with a more or less gentle slope.

On the other hand, the upper line of Chalk cliffs

[1] *Geol. Mag.* (Dec. 1), vol. iv. 1867.

often rises and falls considerably, while those of escarpments present a comparatively uniform level for long distances.

Again, the land often rises behind a Chalk cliff, while an escarpment is nearly always the highest ground in the neighbourhood.

Lastly, while sea cliffs pass from one rock to another, escarpments always keep to one geological formation.

In Kent the Chalk escarpment and the Chalk cliff cut one another obliquely, and the differences may be well seen.

It is indeed now generally admitted that the Chalk and other escarpments are due to aerial action.

The mode of the formation of escarpments explains the, at first sight, curious fact that they are so generally cut through by rivers—thus the Chalk escarpment by the Thames; the Silurian escarpment of Wenlock Edge by the Severn; the eastern Oolitic escarpment by the Great Ouse, the Witham, the Welland, the Wen; the western escarpment south of Ledbury by the Leadon; and the Chalk escarpment surrounding the Weald by the Wey, Mole, Darenth, Medway, Arun, Ouse, Adur, and Cuckmere. The reason of this is, as will be shown in a subsequent chapter, that the rivers established their courses before the strata were eaten back to their present boundary-lines.

But although the present configuration of the surface is mainly due to denudation, the process is very slow. Croll estimated the present mean rate

at one foot in 3400 years, but Davison has given[1] reasons for thinking that a foot in 2400 years is more probable. In the Thames area it is estimated that the general surface is lowered about an inch in 800 years, so that even since the time of the Romans the difference would be quite inappreciable. The rate of denudation was, however, doubtless more rapid before rain and rivers had so much lowered the level. Sir A. Geikie estimates that it would take $5\frac{1}{2}$ millions of years to reduce the British Isles to the sea-level.

SCREES

When mountain-sides are precipitous, the action of the weather, and especially of frost, detaches fragments, which eventually slide down and form a slope, scree (Fig. 86), or talus, at an angle which depends on the nature of the material, but may be taken at about 35°. Such slopes are known as glitters in Northumberland, glyders in North Wales, clatters or clitters in Devonshire, names evidently having reference to the sound of falling stones, and which have in some cases been applied to particular mountains or hill-sides. It is evident that as the mountain crumbles away the scree will creep up until it reaches the summit, and the mountain is buried under a covering of its own debris. Mam Tor, in Derbyshire, is also known as "The Shivering Mountain," from the continual rock-falls which take

[1] *Geol. Mag.* (Dec. 3) vol. vi. 1889.

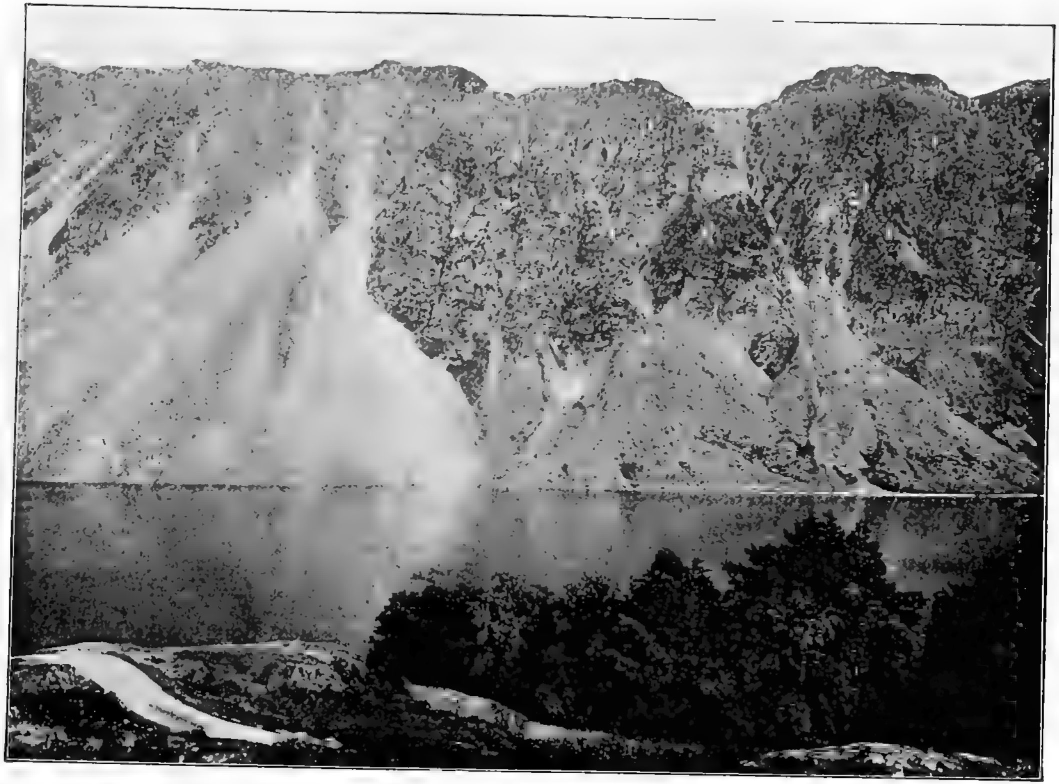


Fig. 86.—Part of Wastwater.

place on its steep sides. Fig. 86 represents Wast-water, one side of which presents a magnificent series of screes.

Screes are naturally more developed in some places than in others, according to the nature of the material; and where the mountain-side is very lofty they sometimes collect into rivulets of stones. A remarkable series of such stone rivers occurs along the south bank of the Rhone valley for some distance above the Lake of Geneva. In wet weather these channels are often adopted by torrents, so that what is generally a river of stones becomes occasionally a true water-course. The stone rivers, like true rivers, tend to form cones or fans when they reach the plain.

The angle at which screes stand is often greatly exaggerated. It seldom exceeds 36°.

Landslips on a larger scale also occur from time to time. The beautiful scenery of the under-cliff of the Isle of Wight is mainly due to the sliding of the Chalk and Upper Greensand, which have a seaward slope and rest on the unctuous surface of the Gault, which has received the name of the Blue Slipper, from its tendency to give rise to landslips. Though the greater part of the under-cliff is prehistoric, considerable movements have taken place even recently. One occurred in 1799, and was described by Norman in the *Isle of Wight Magazine* as follows: "The whole of the ground from the cliff above was seen in motion. . . . The ground above, beginning with a great founder at the base of the cliff immediately under St. Catherine's Down, kept gliding forward,

and at last rushed on with violence, totally changing the surface of all the ground to the west of the brook that runs into the sea, so that now the whole is convulsed and scattered about, as if it had been done by an earthquake."[1] Another great slip took place in 1810, and others have occurred from time to time ever since.

Another remarkable landslip is that which occurred in 1839 between Lyme Regis and Axmouth, which was described by Conybeare.[2] The cliffs consist of chalk, resting on sandstone covering a layer of loose sand, below which again is a stiff clay, shelving towards the sea. The rain soaking through the chalk, but held up by the impervious clay, gradually washed out much of the sand, and the chalk thus undermined began to slip down towards the sea. The catastrophe began on the morning of the 24th December with a crashing noise, and in the evening large fissures had opened in the ground, and a deep chasm was formed three-quarters of a mile long, 100 to 150 feet deep, and over 240 in breadth. The whole cliff was carried bodily forward for many yards, and the weight pressing forward on the strata below the shingle, forced them up in a reef which extended in front of the cliff.

In 1575 there was a great landslip on the eastern side of the valley of Woolhope, thus quaintly described by Camden:[3] "Near to the confluence of the Lugg and Wye to the east, a hill called Marclay Hill, in the

[1] *Mem. of Geol. Surv.*, Isle of Wight.

[2] See also Lyell, *Principles of Geology*, vol. i.

[3] *Britannia*, vol. ii. See also Murchison, *Silurian System*.

year 1757, rose as it were from sleep, and for three days moved on its vast body, with an horrible noise, drawing everything before to an higher ground, to the great astonishment of the beholders, by that sort of earthquake I suppose, which naturalists call *Brasmatia*."

There have also been striking landslips near Ludlow, where masses of Aymestry limestone have slid down, exposing the sloping surface of Lower Ludlow rock.[1]

SUMMARY

Thus then the general history of the earth during geological times appears to have been one of gradual contraction, accompanied by fractures and faults, subsidence and foldings. Those parts which solidified first were best able to retain their position; they sank less, and formed great plains or "horsts" (see ante, p. 179).

When a line of weakness was once established, fracture and folding would follow it over and over again. Hence we find elevation and depression following the same lines at very different periods of the earth's history. There is, moreover, a constant tendency for the oceans to increase in depth, and hence by draining away the water to counteract the wear and tear of the shores.

These wonderful contortions and fractures give in the first place an impression of sudden and cata-

[1] Murchison, *Silurian System*.

strophic changes; and in the second place it is difficult to believe our own eyes, as it seems almost impossible that solid rocks could be bent without breaking. No doubt, however, the process was very slow. If we take a stick of sealing-wax and bend it quickly it will at once snap, but if the pressure is applied very slowly it may be bent almost into a circle. Again, it must be remembered that the strata which were folded were covered by others, and in many cases were at a great depth. The bending may also have been facilitated by heat and moisture. The contortions of the rocks belong, of course, to very different periods.

As the cooling and consequent contraction of the earth is a continuous process, it follows that mountain ranges are of very different ages; and as the summits are continually crumbling down, and rain and rivers carry away the debris, the mountain ranges are continually losing height.

It has indeed been suggested by some high authorities that the Scotch Highland area "would appear to have remained more or less continuously in the condition of land" since the commencement of Old Red Sandstone times.[1] If we make allowance for the expression "more or less continuously," this is perhaps correct, but no land-surface could, I think, have existed permanently so long, as it would have been worn down to or even below the level of the sea, unless indeed the denudation were counteracted by a slow

[1] See, for instance, James Geikie, "On Mountains," *Scottish Geog. Mag.* vol. ii. 1886.

process of elevation. No doubt, however, the Highlands of Scotland, the Lake District, and the Welsh hills are of great antiquity. In comparison the Alps and Himalayas are but of yesterday. It is probable that the Highlands, Lake District, and Wales were the sites of lofty mountains long before the Chalk was deposited at the bottom of the sea.

But though the Alps are so recent compared with the Welsh mountains, it is probable that the amount which has been removed even from them is almost as great as that which still remains. The delta of the Rhone, the plain of Lombardy, Belgium, Holland, and the Dobrudscha are built up in part of materials from the tops of the Alps, which, if no fresh elevation take place, will be gradually lowered until nothing but the stumps remain.

In the case of our Welsh, Cumberland, and Westmoreland mountains, the amount of denudation has been enormous.

Rain, frost, and rivers are still gradually lowering the surface of the land, disintegrating the hard rocks and converting them, with the help of animal and vegetable life, into rich soil suitable for the sustenance of man.

When we regard the surface of the earth we are impressed by a feeling of permanence and antiquity. If we wish to give an idea of strength and of age we say as "firm as a rock," or "as old as the hills." In fact, however, no rock is firm, no hills are old. Granite crumbles away, and the hills are carried into the sea. The ocean, on the other hand, is outside

time. If we were to look back even but 100,000 years, the land would show strange changes; changes in the animals, in the plants, in the mountains, and the rivers. But if we were to go back 1,000,000 years, the ocean would look just as it does to-day.

The movements of elevation and subsidence, of which in this chapter I have endeavoured, very feebly, no doubt, to convey some idea, are still in operation.

For ages yet to come the earth will continue to contract; the crushing and folding of the strata must necessarily follow; and though we may see no evidence of change, the slight shocks of earthquake which occur in our island from time to time show that these gigantic forces are still in operation, and that movements, irresistible though slow, are still taking place under our feet. These considerations cannot, surely, but intensify the wonder and admiration with which we regard such scenes, and deepen the inspiration we feel from the influence of mountain scenery.

CHAPTER VII

VOLCANOES

THOUGH we have now no active volcanoes in the British Isles, much of our most beautiful scenery is due to the volcanoes of bygone ages.

The dislocations of the surface which followed the line of the great Atlantic depression gave rise to volcanic action at more than one place and more than one time along our western coast.

The highest mountains in Wales—Snowdon, Cader Idris, Carnedd Llewellyn; and in England—Scawfell Pike, Scawfell, and Helvellyn, consist, in part at least, of volcanic or plutonic rocks, as do also the Malverns, the Wrekin, Dartmoor, and the Cornish heights.

Our English volcanoes belonged to very different periods. The igneous rocks of Charnwood, Caer Caradoc, the Wrekin, and Malvern are probably pre-Cambrian; some of the North Welsh rocks, those near Nuneaton, some at any rate of the Malvern, are Cambrian; Cader Idris, Snowdon, Moel Siabod, Rhobell-fawr, Y-Foel-Fras, the Arenig Mountains, the largest and most important perhaps, of all, the igneous region of the Lake

District, are Silurian; the Cheviot Hills, some of the granite bosses, that of Shap, for instance, and some of the Devonshire series, may be referred to the Old Red Sandstone; the toadstones and sills of Derbyshire, the lava and tuff of the Mendip Hills, Brent Tor, and some of the other igneous rocks of Dartmoor, to the Carboniferous period.

Some volcanic deposits in the centre of England, the Clee Hills, for instance, in the Coalbrookdale and South Staffordshire coal-fields, and certain rocks in the Devon and Cornwall district, are referred to the Permian.

After this came a long period of quiescence; so far as Britain is concerned we have no evidence of any volcanic activity from the close of the Permian until we reach Tertiary times.

Some of the dykes of our northern and central districts belong to this period, but, so far as the British Isles are concerned, the great scenes of volcanic energy during the Tertiary period were the North of Ireland, the Hebrides, and the West of Scotland.

When we speak of volcanoes, we think, naturally, of mountains more or less resembling Vesuvius or Mount Etna. Volcanic eruptions, however, belong to several distinct types.

Sir A. Geikie, in his admirable work on *The Ancient Volcanoes of the British Isles*, considers that they fall into three well-marked divisions:—

1. The Vesuvian type, in which rocks and lavas are ejected from a central crater, which is gradually built up round the chimney. The lava flows down

the slopes, and minor vents appear from time to time at various heights on the sides. Ashes and dust are also thrown far and wide over the surrounding country. To this type belonged the volcanic eruptions in the Snowdon, Cader Idris, and Arenig districts.

2. The plateau or fissure type, which is developed on the grandest scale in Iceland. No special cone is formed, but the ground is split open into long fissures, sometimes only a few yards, or even feet, in width, but extending for miles across country, and descending to an unknown depth. From these fissures lava wells up, sometimes tranquilly, sometimes accompanied by discharges of ashes and great blocks. This type characterises the great basaltic plateaus of Antrim and the Hebrides. The lavas are approximately horizontal, and in some places as much as 3000 feet in thickness. They form level or gently undulating tablelands.

3. The third or the "puy" type is so termed from the "puys" or volcanic cones of France, so admirably described by Scrope.[1] They form conical hills, consisting mainly of fragmental materials and sometimes of lava. Though the action may, and no doubt did, continue for a long period in one district, each of these cones is probably the product of a single eruption. The French puys are all prehistoric, but Monte Nuovo, near Naples, which belongs to the same type, was formed in 1538, and, though more than 400 feet in height, was thrown up in two

[1] *Extinct Volcanoes of Central France*, 1858.

days. Another well-known region of this type is the Eifel.

In our own islands many volcanoes of the first type occur in the Palæozoic rocks. Some of them have been exposed by denudation, and along the coast of Fife, for instance, look so fresh that it is almost impossible to realise their vast antiquity.

It is only when so dissected that their real structure can be seen. The mountains and hills in our volcanic districts are indeed so rugged, and even so conical, that they have often been mistaken for actual volcanoes and craters. As a matter of fact, however, they have all been subjected to great denudation, and the rocks now on the surface were once deep down in the earth.

If the eruptions of Vesuvius were to cease, the rain and other atmospheric influences would gradually strip away the outer ashes and dust and gradually remove even the harder lavas. In such a case, however, the chimney of the volcano, being filled with hard rock, would gradually stand out, forming a more or less conical hill. Many of the volcanic hills are the "necks" or pipes of ancient volcanoes.

Sir A. Geikie has diagrammatically illustrated this in the following figure (Fig. 87).

The original forms of the central volcano and of its parasitic cones are shown by the dotted lines in the upper half of the figure. This dotted part is supposed to be all removed by denudation, and the present surface is shown by the continuous line.

The general structure of the mountain is indicated underneath that line—the lenticular sheets of lava and tuff (*l*), the dykes (*d*), the lavas (*p*), and the agglomerates (*a*) of the central vent and of the daughter cones.

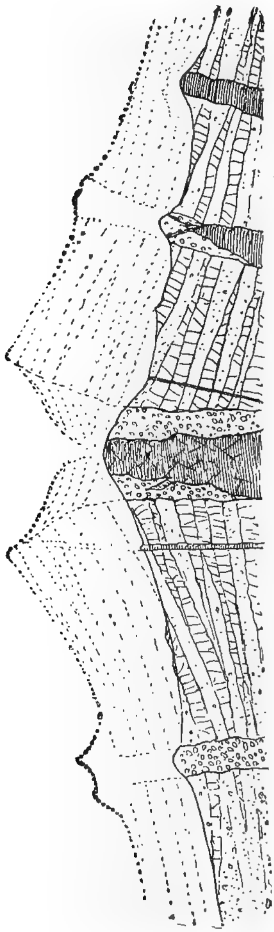


Fig. 87.—Effects of Denudation on a Vesuvian Cone. *l*, Lenticular sheets of lava and tuff; *d*, dykes; *p*, lavas; *a*, agglomerates of the central vent and of the subordinate cones.

Such is the origin of various North Country "Laws,"—of North Berwick Law (Fig. 88), Largo Law, the Bass Rock, Arthur's Seat, the Castle Rock of Edinburgh, etc.

Many of the English vents are not separated from the surrounding strata by any difference of contour, and consequently form no feature in the landscape. Others, as for instance two vents at Grange Mill in Derbyshire, about five miles west of Matlock Bath, which I had the pleasure of visiting with Mr. Bemrose, by whom they have been described, form, however, a marked contrast to the scenery of the surrounding Limestone. They are dome-shaped hills, with grassy slopes and well-marked contours, rising to a height of 100 and

Fig. 88.—View of North Berwick Law from the east, a trachyte neck marking one of the chief vents of the Garleton Plateau.

200 feet respectively above the surrounding surface. The steep sides consist of a grey rock containing green lapilli with a few limestone pebbles, and which weathers into spheroids.[1]

Brent Tor, in Devonshire, might well at first sight be supposed to be an actual volcano. Sir Henry De la Beche long ago said: "The idea that in the vicinity of Brent Tor a volcano has been in action, producing effects similar to those produced by active volcanoes from a similarity of causes, forcibly presents itself. That this volcano ejected ashes, which, falling into adjacent water, became interstratified with the mud, silt, and sand there depositing, seems probable. That Greenstones and other solid trappean rocks constituted the lavas of that period and locality seems also a reasonable hypothesis. Upon the whole, there seems as good evidence as could be expected, that to the north and north-west of Tavistock, ash, cinders, and liquid melted rocks were ejected, and became intermingled with mud, silt, and sand during this ancient geological epoch, corresponding with the phenomena exhibited in connection with volcanoes of the present day."

As a matter of fact, however, it is not really itself a volcano—but only a portion of the volcanic ejections and lava, probably of Carboniferous age, from some not far distant volcano, which, as well as the rest of the lava, etc., has disappeared. Why they have disappeared and this fragment only remains has not yet been satisfactorily explained, but Rutley

[1] Arnold Bemrose, *Proc. Geol. Ass.* vol. xvi. 1899.

suggests[1] that it has been preserved in consequence of having been let down by faults.

The vents or necks vary much in size. Some are only 100 feet, or even less, in diameter. The larger of the two vents at Grange Mill measures 2400 feet by 1300. In form they are more or less rounded or oval, and sometimes two or more are close together. The vents have generally been filled up by agglomerates of stones which fell back into the crater or tuffs, in other cases by lava, or partly by the one and partly by the other. Sometimes they are filled with non-volcanic debris which has fallen in.

It is remarkable that where a chimney has been blown through stratified rock, especially if the layers are nearly horizontal, they almost always dip towards the chimney. This is not what might have been expected. It has been suggested that the ejection of great masses of material might have left hollows into which the sides eventually subsided. The dip, however, appears greater and more abrupt than this explanation would suggest, and the true reason still seems doubtful.

It is by no means easy in all cases to determine the position of the actual vent from which lava streams were ejected.

Ward believed that one of the main volcanic centres of the Lake District was the Castle Head, to the south of the town of Keswick; the round boss of intrusive dolerite representing the solidified lava far below the surface, while the crater from which

[1] *Mem. Geol. Surv.*, Brent Tor.

flowed the lavas of Wallow Crag was, of course, far overhead. This, however, has since been questioned.

The rocks surrounding the necks are, as might naturally be expected, baked and altered by the heat. This is especially the case in those necks which, from their greater size, may naturally be supposed to have been longer in operation, and to have risen to higher temperatures. In such cases shales are baked into porcellanite, coal-seams are burnt, and limestones have been turned into marble. The alteration may extend to a distance of 15 to 20 yards.

We have in England no groups of basaltic columns comparable to those of Staffa or the Giant's Causeway; but a beautiful example of slender columns is described by Murchison in *The Silurian System*, in the Pearl Quarry in Timmins Hill. They are not less than 30 feet in length, and a few inches only in width. In Tansley Hill also are some fine examples of similar slender prisms.

PLATEAU OR FISSURE TYPE

Coming now to the second class of volcanic phenomena, we find the North-west of England traversed by thousands of dykes containing volcanic matter. In Iceland and other volcanic regions cases have occurred even in historical times where fissures have opened at the surface and have filled with lava, which has sometimes overflowed in great sheets, and eventually solidified.

Such fissures are by no means rare during eruptions of existing volcanoes.

In Hawaii, after the earthquake of 1869, the ground was split along a line many miles in length, and shifted laterally about 18 feet, so that where the crack crossed the road from Kona to Waiohina the left hand of the road on one side was brought in line with the right hand on the other side.[1]

Again, on Etna, "a fissure 6 feet broad, and of unknown depth, opened with a loud crash, and ran in a somewhat tortuous course to within a mile of the summit of Etna. Its direction was from north to south, and its length 12 miles. It emitted a most vivid light," indicating "that the fissure was filled with incandescent lava, probably to the height of an orifice not far from Monte Rossi, which at that time opened and poured out a lava-current."[2]

It cannot be doubted that many at any rate of the ancient dykes were connected with lava sheets which have since been denuded.

It is remarkable that while dykes differ greatly in thickness, up to the great example at Beith, which attains a maximum width of 640 feet, each dyke often retains the same width for a great depth and great distance. Some dykes which have been followed from deep valleys up to the hill-tops have been found to retain very nearly the same width for a vertical height of 2000 or even 3000 feet.

The Great Cleveland dyke, the largest in Great

[1] Green, *Vestiges of a Molten Globe.*

[2] Lyell's *Principles of Geology,* vol. ii.

Britain, runs with a general west-north-west direction from Maybechs in the east to Armathwaite in the west, a distance of about 90 miles, and it is probably continuous with one which appears to the north of the Solway and runs into the Clyde near Prestwick, in which case its total length would be no less than 190 miles. It has been subject to several shifts and local deviations. Between Menthorpe and Stainton it is shifted about half a mile to the south, and at Preston it makes an abrupt bend at a right angle. It varies from 20 to nearly 100 feet in thickness, and expands near the village of Bolam, attaining a width of 200 to 300 yards. This dyke often dies out before attaining the surface. It is constant in character, and different from any other rock known in the North of England.[1] It crosses the Oolitic Sandstones of Yorkshire, so that it must be Post-Jurassic, and is probably of Miocene age.

In different parts of its course this remarkable dyke cuts through Lias, New Red Sandstone, Coal-measures, Millstone Grit, and a great thickness of Silurian rocks, so that it probably rises from a depth of more than 17,000 feet. How tremendous the force must have been to raise this enormous mass of matter from so great a depth!

The Acklington dyke has been traced from the Northumberland coast far into Scotland, and is considered to be of Eocene or Miocene age. It is a fine-grained basalt.

When the materials of the dykes are more durable

[1] Teall, *Quar. Jour. Geol. Soc.* vol. xl. 1884.

than those of the surrounding rocks, they stand out as craggy projections, running in conspicuous lines across the country.

Those, on the contrary, which weather more rapidly than the surrounding rock form depressions or gullies, with steep sides, and are known in the Lake District as "doors," such as Mickledoor, Combdoor, etc. Scawfell Pike is separated from Scawfell by a deep rut, known as "Mickledoor," which is due to such a dyke.

Fig. 89.—Section across Teesdale.

Dykes differ much in direction, but there is a prevailing tendency to the north-west.

They are generally vertical or nearly so, but there are other and perhaps even more remarkable sheets of plutonic rock which are nearly horizontal, and are known as "sills." These are not sheets of lava which flowed out on the surface, but intrusive material, which has been injected between the strata. They range from an inch or so up to several hundred feet in thickness.

The greatest of these intrusive sheets is that in the North of England known as the Great Whinsill, to which the striking scenery of Teesdale is mainly due. It can be traced for a distance of about 80 miles, from Burton Fell on the Pennine escarpment to

Bamborough and the Skerries beyond Farne Island. One of the finest sections is at High Cup Nick, about 4 miles east of Appleby, where it has conspicuously baked and altered the shale-beds above as well as below, showing that it is an intrusive sheet, and was not spread out on the surface. It covers an area of probably 1000 square miles, and varies in thickness from 20 to 150 feet, averaging from 88 to 100. In character it is very uniform —a dolerite or diabase, generally coarsest where it is thickest, and finer in grain above and below than in the centre. Its intrusive character was finally established by Topley and Lebour. It lies approximately parallel to the Carboniferous strata, into which it was injected, but does not follow throughout any particular horizon, passing transgressively across at least 1000 feet of strata. It is, of course, more recent than the Carboniferous strata in which it occurs, but how much later we do not yet know. It is a remarkable feature in the geology and scenery of the North of England, and has given rise to the famous waterfalls known as High Foss and Cauldron Snout. The channel or channels which served as chimneys for the material of the Whinsill have not yet been discovered. It is difficult to form any idea of the manner in which such a sheet could be injected; and on the other hand, the idea that the molten matter gradually ate its way into and absorbed the older rock, also presents great difficulties.

It is evident, however, that the sills have been intruded into pre-existing rocks, because the surrounding

strata have been altered both above and below. The Tideswell Dale sill in Derbyshire lies on a bed of clay, which it has baked to a depth of 9 feet and, as Mr. Bemrose was good enough to show me, converted into small pillars, resembling in miniature those of Staffa or the Giant's Causeway.

The total thickness of volcanic rock is in some places immense; that of North Wales can hardly be less than 6000 to 8000 feet. Ward estimated that of the Lake District at 12,000 or even possibly 15,000 feet.

The Cornish miners apply the term "Elvan" to quartz-felsite or quartz-porphyry, often of a whity-brown colour. They are sometimes several fathoms in thickness, and cross both granite and slates. They are sometimes fissile, but often afford an excellent stone for building or road-making.

Igneous rocks are often divided into two classes, those containing much silica and those with less. The former generally fuse at a higher temperature and cool more slowly than the latter. Hence they often form massive bosses, as, for instance, the granites; while basalt, which belongs to the latter class, forms large sheets. The rule, however, is by no means without exceptions. Those with much silica are termed "acid," those with less, "basic."

As Sir A. Geikie has pointed out,[1] many of the lavas which have been superficially erupted weather into irregular craggy hills, like the flanks of Snowdon. Those of intermediate composition, when in thick

[1] *Ancient Volcanoes of Great Britain.*

masses, as in the Cheviot, Pentland, and Garleton Hills, often weather into conical forms; or if poured out in thin sheets, build up undulating platforms. "Basic" lavas, if in thin sheets, form flat-topped hills and terraced escarpments, of which the Inner Hebrides afford many characteristic examples.

Where lavas and tuffs are associated, the tuffs, being generally more friable, decay faster and give rise to hollows, while the lavas project in bold ridges or escarpments.

CHAPTER VIII

OUR ENGLISH MOUNTAINS AND HILLS

"Erst dann haben wir ein Gebirg erkannt, wenn sein Inneres durchsichtig wie Glas vor unserm geistigen Auge erscheint."—THEOBALD.

"We do not really know a mountain until its interior is to our mental eye as clear as crystal."

STRICTLY speaking we have no range of mountains in England, I might almost say in Great Britain. Our so-called mountain ranges are either parts of elevated districts which stand out from the greater hardness of the rocks of which they consist, such as the mountains of Wales and of the Lake District, or they are lines of escarpment (see ante, p. 218), originating like the Cotteswolds, the Chilterns, and the North and South Downs.

If, however, our mountains are insignificant so far as mere height is concerned, they are venerable from their antiquity, and need yield to none in interest. We are apt to look on mountains as types of antiquity; but mountains are not everlasting, nor are they by any means all of the same age. The antiquity of the Alps and the Himalayas is little compared to that of our Scotch and Welsh mountains, which indeed are so low because they are so old.

We must often have wished that we could look into the heart of some great mountain chain, and in fact our mountains enable us to do so. They show us what we might find if we could penetrate into the heart of the Andes or the Himalayas. From this point of view, and from their vast antiquity, they certainly are of extreme interest.

The following figures give the heights of some of our principal mountains :—

Snowdon, 3571 feet.
Carnedd Llewellyn, 3469 feet.
Scawfell, 3162 feet.
Helvellyn, 3118 feet.
Skiddaw, 3054 feet.
Cader Idris, 2929 feet.
Cross Fell, 2892 feet.
Brecknock Beacon, 2862 feet.
Saddleback (Blencathra), 2847 feet.
Cheviot, 2676 feet.
Mickle Fell, 2596 feet.
Plynlymmon, 2469 feet.
Whernside, 2414 feet.
Ingleborough, 2373 feet.
Penyghent, 2270 feet.

And of the more interesting but lesser heights I may mention :—

Yes Tor, Dartmoor, 2050 feet.
The Peak of Derbyshire (Kinder Scout), 1981 feet.
Brown Clee (Shropshire), 1805 feet.
Dunkery Beacon (Exmoor), 1707 feet.
Longmynd, 1674 feet.
Malvern Hills, 1396 feet.
Brown Willy (Cornwall), 1368 feet.
The Wrekin, 1320 feet.
The Quantocks (Willsneck), 1262 feet.
Caradoc, 1250 feet.
Cleeve Cloud (Oolites), 1093 feet.
The Lickey Hills, 1028 feet.
Inkpen Beacon (Berkshire) (Chalk), 1011 feet.
Leckhampton Hill, 978 feet.
Leith Hill (Lower Greensand), 965 feet.
Marlborough Downs (Chalk), 967 feet.
Bredon Hill (Oolite), 961 feet.
Hindhead (Lower Greensand), 894 feet.
Charnwood Forest, 850 feet.
Crowborough Beacon (Hastings Beds), 803 feet.

Our English mountains fall into several classes.

1. Mountains due to the hardness of volcanic matter—lava, compressed ashes, etc., as, for instance, many of the mountains of North Wales and the Lake District.
2. Those due to granite, as the Cheviots, Shap, Dartmoor.
3. Those due to hard sedimentary rock, as Skiddaw, the Peak, the Brecknock Beacon, etc.
4. Escarpments due to the outcrop of hard beds, as, for instance, the Pennines, Wenlock Edge, Axe Edge, Alderley Edge, the Cotteswolds, Chilterns, North Downs and South Downs.

In describing our English mountains we might commence with Snowdon, and take them according to height; or with the Cheviots, and come gradually south; but in either case we should be compelled to separate mountain groups which are really very similar in character. On the whole, it seems best to take them according to the age of the central rock, though the result is that we must begin with some which are of no great altitude, and which indeed on account of their age have been worn down, so to say, to mere stumps. It is hardly necessary to observe that, though a mountain cannot be older than the rocks of which it is composed, the date of the elevation may be much more recent.

If not the oldest, at any rate amongst the oldest, of our English rocks are those of the Wrekin, Charnwood Forest, the Malverns, Caer Caradoc, the Longmynd area, parts of Anglesey, the mountains of Wales and the Lake District, to which may be added the granite bosses of Devon and Cornwall.

The Wrekin (Fig. 90) is a chain of hills in Shropshire stretching from north-east to south-west,

about 1320 feet in height and 29 miles in length, or, if we include the elevations west of Kington in Herefordshire and Radnorshire, which are probably composed in part of rocks belonging to the same series, we might say 50 miles. They do not form a continuous range, but a series of hills.

The central boss[1] is the exposed apex of a mass of bedded felspathic lavas and tuffs. It may perhaps have been an ancient volcanic vent. Round it are other igneous deposits, fringed by quartzites which

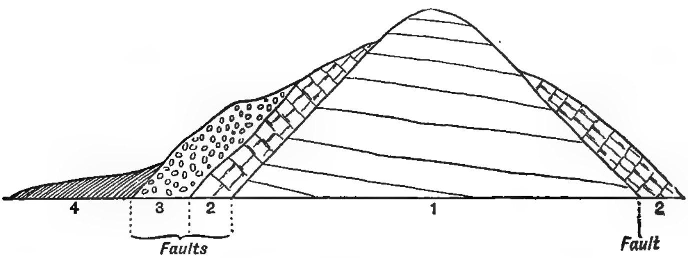


Fig. 90.—Section across the Wrekin, scale about 8 inches to 1 mile. 1, Bedded pre-Cambrian volcanic tuff, dipping north; 2, Quartzite, probably pre-Cambrian; 3, Hollybush sandstone; 4, Shineton shales (Cambrian).

dip away from the axis at a high angle, and are broken through in one place by a mass of greenstone. Callaway has suggested that the crest of the Wrekin was an island in the pre-Cambrian ocean, and that its denudation furnished the felstone fragments embedded in the quartzite.[2] However this may be, the rocks of the Wrekin are probably amongst the most ancient in the British Isles.

Some authorities refer the quartzite (Fig. 90, 2)

[1] See Callaway, "Pre-Cambrian Rocks of Shropshire," *Quar. Journ. Geol. Soc.* vol. xxxv. 1879.

[2] Symonds (*Records of the Rocks*) considered that the elevation of the Wrekin, like that of the Malverns, took place during Permian times,

to the Cambrian period. Callaway has detected in it a good specimen of a worm-burrow, which he regards as the oldest known British fossil.

The Malverns attain a height of 1400 feet, and when seen from the low ground of the valley of the Severn present one of the most striking features in the interior of the kingdom; from the west, however, the view is interfered with by other high ground.

The central core of the hills consists of gneiss, considered to be Archæan, and flanked by sandstone containing Trilobites (*Olenus*), which are of Cambrian age.

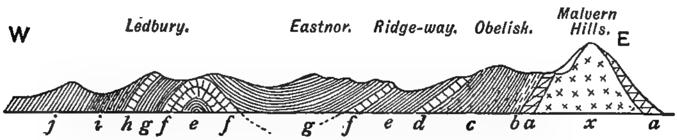


Fig. 91.—Section from Ledbury to the Malvern Hills. *j*, Lower Old Red Sandstone; *i*, Upper Ludlow; *h*, Aymestry limestone; *g*, Lower Ludlow; *f*, Wenlock limestone; *e*, Wenlock shale; *d*, Woolhope beds; *c*, Upper Llandovery sandstone and conglomerate; *b*, Hollybush sandstone and black shale, with Olenus; *a*, Felspathic rocks; *x*, Gneissic rocks, Archæan.

It has been supposed by some to have been the root of an ancient volcano. This has recently been questioned by Groom,[1] who observes that there are "no truly vesicular rocks and tuffs," as has erroneously been supposed. The amount of denudation has, however, been very great, and it is possible that they may have long since been removed. The rock is an intensely folded and faulted complex of Archæan, Cambrian, and Silurian rocks, and the elevation probably took place at several successive periods, ranging perhaps from the Cambrian to the Jurassic.

[1] *Quar. Journ. Geol. Soc.* vol. lvii. 1901. Professor Groom gives an epitome of the literature on the subject.

Phillips long ago observed that some of the Malvern Hills—Raggedstone, for instance—show two summits side by side. Holl has shown that the eastern and western sides differ in structure and lithology, and that the depression lies along the line of fracture separating the two. Wintercombe is a similar line of depression between Midsummer and Hollybush Hills, and is due to a mass of sandstone, conglomerate, and gneissose rock so much shattered as to be more easily disintegrated. The Gullet Pass, between Midsummer and Swinyard Hills, is also a line of dislocation. In the Malverns some of the strata are perpendicular, and others, as already mentioned, are even inverted.

The shadow of Raggedstone Hill, according to a popular legend, was supposed to bring ruin on any one on whom it fell. Cardinal Wolseley's disasters were accounted for by the fact that when as a young man he was chaplain at Morton Court he went to sleep one day in the garden, and the fatal shadow fell upon him.[1]

Caer Caradoc (Fig. 92) is considered to be called after Caractacus, and has been supposed by some to have been the site of his last battle against the Romans under Ostorius Scapula. Like the Wrekin it is a wedge of pre-Cambrian eruptive rock, bounded by faults on all sides, and thrust up through younger deposits.[2] The rock itself consists of felspathic grits, felstones, ashy shales, and indurated claystones, with several protrusions of greenstone. It is a ridge

[1] Symonds, *Excurs. Geol. Ass.* 1860-90.

[2] *Quar. Journ. Geol. Soc.* vol. xxxv. 1879.

between seven and eight miles long, half a mile wide, and about 1200 feet in height.

Charnwood Forest is a surprising contrast to the scenery of the surrounding country. It looks like a bit of Wales transported into the middle of England, and indeed it is an outlier of the Welsh rocks which has been protruded through the surrounding Secondary strata. It is a tract of high ground enthroned in the midst of plains, a solitude in the middle of a thickly peopled district, a wilderness in the middle of mines and manufactures. The rocks are no doubt of ex-

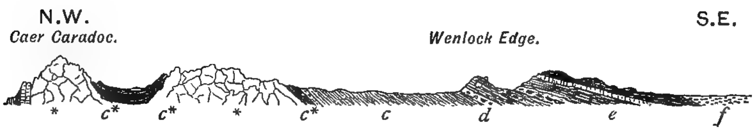


Fig. 92.—Relations of Caradoc sandstone to the Upper Silurian rocks in Shropshire. *, Igneous rocks; c*, Caradoc sandstone altered by eruptive rocks; c, Caradoc sandstone, etc.; d, Wenlock rocks; e, Ludlow rocks; f, Old Red Sandstone.

treme antiquity—Cambrian, if not pre-Cambrian; but there is great doubt as to the period of their elevation. Outliers of the Charnwood rocks occur at Enderby, Narborough, Croft Hill, and elsewhere.[1]

The Lickey Hills, Worcestershire, consist mainly of quartzite much resembling that of the Wrekin. The ridge is now only a few hundred yards in width, but was once evidently very extensive, and the hills have become celebrated because, as Dr. Buckland long ago observed, they have furnished a large proportion of the pebbles of the New Red Sandstone and the Drift. They rise to a height of a little over 1000 feet.

[1] Woodward, *Geol. of England and Wales.*

The Stiper Stones (Fig. 93) consist of sandstone, passing into crystalline quartzite, and extend for 10 miles, from Pontesbury near Shrewsbury, to Snead near Bishops Castle. They jut out on a lofty moorland and rise to a height of 1600 feet, and are considered to belong to the Cambrian period. "From the summit is a fine panorama of the Welsh mountains, with the old volcanic Corndon in the foreground, and Plynlymmon and Cader Idris in the extreme distance. . . . The Longmynd range bounds the view to the east. . . . Caer Caradoc stands boldly out at a little distance to the north-east, with the Wenlock and Aymestry Limestone ridges beyond."[1]

The Stiper Stones "stand out on the crest of the ridge at short intervals, like rugged cyclopean ruins, some of the principal of which are about 50 or 60 feet high, and about 120 or 130 feet in width."[2] The main range is from N.N.E. to S.S.W.

The Longmynd Hills (Fig. 93) rise to a height of 1600 feet. They consist of grey, green, and purple grits, sandstones, conglomerates, and slates, and stand almost vertically, as shown in the section. The interval of time between these rocks and the Silurian must have been very great, as is shown by the fact that the Cambrians were tilted before the Silurians, which lie on their upturned edges, were deposited.

Though very ancient, and probably of Cambrian age, the Longmynd rocks themselves are long

[1] Symonds, *Record of the Rocks;* Woodward, *Geol. of England and Wales.*

[2] *Proc. Geol. Ass.* vol. iii. 1872.

subsequent to the Wrekin, as is proved by the fact that pebbles of the Wrekin rocks occur in them.

Cader Idris (Fig. 94), situated in the south of Merionethshire, consists of inclined beds of slate, porphyry, and volcanic matter, originally no doubt beds of ashes and lava. That which forms so much of the north front of the mountain is about 1000 feet in thickness.

"On the upper slopes[1] of Cader itself the main geological features on which the landscape depends are clear and simple. A vast mass of felspathic porphyry forms the precipitous front of the lofty cliff that, 7 miles in length, ranges from Craig-cwm-llw on the west to Mynydd Moel and Geu Graig on the east, and the strike of this rock, with its underlying strata of slates and ashes all dipping south, is easily visible even to the inexperienced eye in the long lines of varied colour that run along the face of the cliff east and west of the peak of Cader Idris."

The actual summit consists of a thick mass of vesicular porphyry,[2]

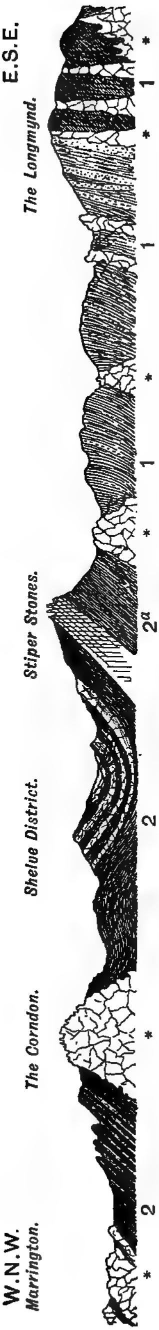


Fig. 93.—Section from the Longmynd on the E.S.E. across the Stiper Stones to the tract of Shelve and Corndon on the W.N.W. 2, Llandeilo formation with trap rocks; 2*a*, Schists and sandstones (base of Silurian life); 1, Longmynd or bottom rocks; *, eruptive rocks.

[1] Ramsay, *Mem. Geol. Surv.* vol. iii. North Wales.
[2] Mackintosh, *Scenery of England and Wales.*

Fig. 94.—Cader Idris.

about 1000 feet in thickness. On the surface the vesicles are often empty, but in the body of the rock they are filled either with quartz or carbonate of lime, or sometimes with a mixture of the two. The porphyry forms the dark and broken mounds that roughen the slopes above Llyn Cau. The slate in contact with it has been altered by the heat, and rendered hard and porcellaneous.

The greenstone is often beautifully columnar, and the porphyry is sometimes so regularly jointed that it forms symmetrical columns which are often used for gate-posts. The Tremadoc slates are in parts turned into a kind of porcellanite or hornstone, hard, white, and flinty. The eruptions to which Cader Idris is due were long anterior to those of Snowdon.

Speaking of the cliffs on the south-east side of the mountain, Mackintosh tells us that he "knows of no wall of rock in South Britain which combines the characteristics of continuity, steepness, length, height, and bare rocky grandeur to so great an extent as the northern rampart of this mountain."[1] The total length of the cliff, including the windings, is about ten miles, and it extends this whole distance without a break or buttress.

Snowdon (Figs. 95 and 96) is the loftiest of our English mountains, and with the surrounding summits —Carnedd Llewellyn, Y-Foel-Fras, Carnedd Dafydd, Y-Glyder-Fach, Y-Glyder-Fawr, and Moel-Hebog —forms the highest, wildest, and grandest parts of North Wales.

[1] Mackintosh, *Scenery of England and Wales.*

The mountain consists of igneous rocks interbedded with thick bands of fossiliferous grits and slates belonging to the Silurian period, and indicating long periods of repose between the eruptions. Somewhat to the north there are three distinct lava-flows. The igneous rocks themselves are rather over 3000 feet in thickness. This, however, only includes the higher part of the volcanic series. Below them come the lavas of Y-Glyder-Fach, which are shown by the Survey measurements to be about 1500 feet thick, while still lower again are the ancient coulées from

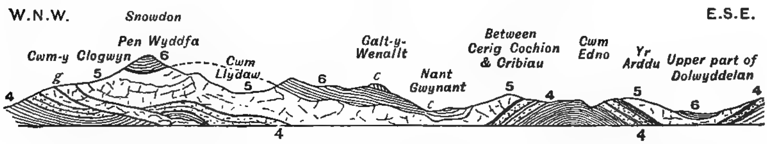


Fig. 95.—Section from Snowdon to Dolwyddelan. 4, Grits, fossiliferous overlying slaty beds; 5, Felspathic porphyry (lava beds); 6, Volcanic ashes, sometimes calcareous and fossiliferous, Bala limestone; *c*, Columnar felspathic traps of Gallt-y-Wenallt; *g*, Greenstone (intrusive).

Carnedd Dafydd and Y-Foel-Fras, so that the whole series must amount to between 6000 and 8000 feet.

Ramsay was disposed to think that the volcanoes from which the Snowdon eruptions took place are perhaps indicated by the series of plutonic bosses forming hills in Carnarvonshire along the promontory of Lleyn (Mynydd Mawr, Carn Madryn, Cefn Amlwch, etc.).

Fig. 95 shows the general arrangement of the strata.

The summit of Snowdon is a shallow syncline; that of Clogwyn-Du'r-Arddu, a spur on the north-west side towards the Pass of Llanberis, is much more marked. Between the passes of Gorfwysfa and Lake

Llydaw is a mass of plutonic rock, at one place showing well-marked basaltic pillars. The volcanic deposits of Snowdon were no doubt once covered by a great thickness of rock, which has since been removed by denudation. The rocks under the eastern escarpment of the mountain, and along the steep slope of Lliwedd, show nearly perpendicular furrows, which might be supposed to indicate stratification, but are really due to cleavage.

The strata are greatly altered by compression, showing often well-marked cleavage, broken through here and there by eruptive masses, intercalated with beds of felspathic porphyry, and covered, in the case of Snowdon, by thick masses of volcanic mud and ashes. The plutonic and volcanic rocks are, however, only indirectly the cause of the mountains and valleys as they now exist, for the disturbances to which these are due took place at a subsequent period, and affected them in the same manner as the marine beds.

The Snowdon district forms a great trough. On Snowdon, Moel-Hebog, Y-Garn, and Carnedd Dafydd the general dip is to the east, while on Y-Glyder-Fawr, Y-Tryfan, and part of Carnedd Dafydd it is to the west; but this great trough contains many minor undulations.

The smooth rounded hills to the south of Cader Idris belong to the same period as, and are similar in composition to, the sedimentary rocks of the Snowdon group; but the jagged and serrated peaks which characterise the latter are due to the porphyries,

Fig. 96.—Snowdon.

greenstone, and other igneous rocks. The beauty of the scenery is also greatly enhanced by the numerous tarns, one of which, with the glaciated rocks round it, is shown in Fig. 7, p. 53.

The great height is not due to the intrusion or piling up of the igneous masses. They were indeed, after the volcanoes became extinct, covered over by several thousands of feet of newer strata, and at length all disturbed together, thrown into great rolling curves, and then denuded, the present mountains being, so to say, carved out, and left at a greater relative elevation, because the hard felspathic igneous rocks of which they consist were better able to withstand degradation than some of the softer slaty rocks with which they are associated. Their hardness is also partly due to their having formed the bottom of a syncline (see ante, p. 96).

This is well brought out in Fig. 96, which represents Snowdon under a sprinkling of snow, thus bringing out the saucer-shaped or synclinal arrangement of the strata more clearly than would otherwise have been the case. It is indeed a remarkable and interesting fact that the rocks forming the highest spot in South Britain should once have been the bottom of a valley.

In the case of Snowdon a small part only of the old valley remains. Where more of the depression is preserved the mountain assumes somewhat the form of a saddle. This is the case with Blencathra (Frontispiece), near Keswick, which is consequently locally known as "Saddleback."

The reason is that, as already mentioned, the strata at the bottom of a syncline are more compressed, and, being therefore rendered peculiarly hard, are less easily destroyed and removed.

Helvellyn, perhaps, owes its height to the hard rock of Swirrel Edge.

Like North Wales, *The Lake District* owes its elevation, its beauty, and its wildness to the presence of hard volcanic rock. Scawfell Pike, the highest point, consists of fine volcanic ash altered into a flinty felstone-like rock, so hard that it was sometimes used for ancient implements.[1] These volcanic rocks belong to the Lower Silurian period, and Ward estimates them as not less than from 12,000 to 15,000 feet in thickness.[2] Like those of North Wales, they are much faulted, and thrown into folds. The rocks also in many places betray the existence of internal movements by the presence of slickensides (see p. 194 and Fig. 63). This is well shown, for instance, in an interesting quarry near Coniston, on the Ambleside road.

Helvellyn, Bowfell, Great Gable, Great Dodd, and the Langdale Pikes are also in the volcanic district. Skiddaw and Blencathra or Saddleback are formed of Cambrian and Lower Silurian slate.

The volcanic series forms a marked contrast to the softer outlines of the Skiddaw slates, the coarse ash and breccia weathering into rough crags.

On Striding Edge (Fig. 97) the strike of the cleavage corresponds nearly with the direction of the

[1] See Sir John Evans, *Ancient Stone Implements.*

[2] *Mem. Geol. Surv.*, Lake District.

Edge. The ash is tolerably fine and flakes readily away, and numerous slips take place along the cleavage planes, especially on the steep side.[1]

Though Scawfell Pike is the highest, Ward describes Blencathra or Saddleback as perhaps the noblest of the Lake District mountains.

Cleavage, he says, "occasionally unites with the true bedding, to give a peculiar character to a mountain; of this Blencathra (Saddleback) is a most noble example. It is composed of flaggy and black slate dipping, on the whole, pretty steadily to the north-west at an average angle of 25°, which corresponds with the slope of the bank of the mountain; but crossing this dip at a higher angle are the cleavage planes, along which the slate mostly weathers, and thus arise the steep-sided front and sharp edges characteristic of this grand mountain."[2]

From Keswick the mountains appear perhaps to their greatest perfection. Standing at one end of a rich, fertile, and well-wooded tract of alluvium uniting the two lakes of Derwentwater and Bassenthwaite, the double-peaked, lofty, but smooth-sided Skiddaw rears his noble front upon the north. Southwards, Derwentwater, with its well-wooded islands, lies nestled among hills of beautiful and varied aspect: upon the one side all craggy, precipitous, and of irregular outline; upon the other, of smoothly sloping aspect and gently curved contour. At the head of the lake opens up Borrowdale, with the round-topped Castle Crag, standing like a sentinel

[1] *Mem. Geol. Surv.*, Lake District. [2] *Ibid.*

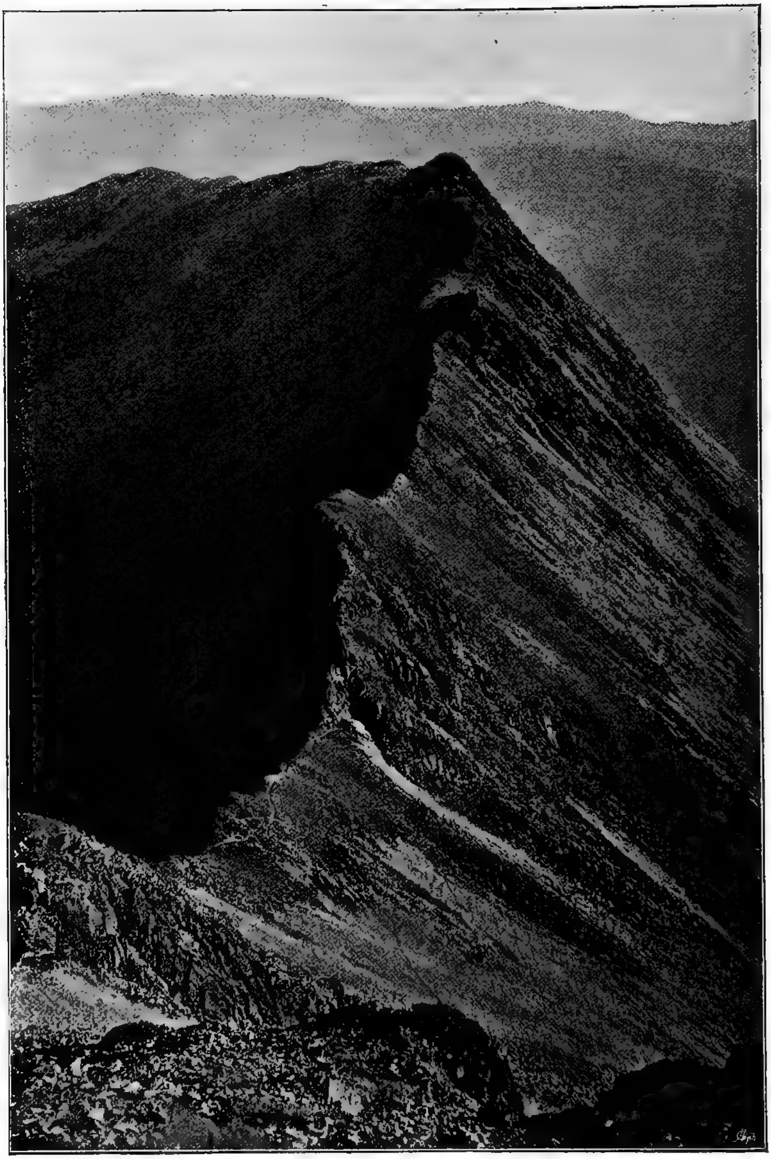


Fig. 97.—Striding Edge, Helvellyn.

at its entrance, and bold, craggy mountains surrounding on all sides the grass-clad valley bottom. As seen from Keswick, the hummocky outline of Glaramara, the straight-edged, lofty cliff of Great End, and the slightly conical form of Scawfell Pike, combine to form a noble background to the view, which indeed in Ward's opinion is "quite unrivalled in British scenery."[1]

Skiddaw, says Hamerton, "is as wild as a Highland Ben, and, though little more than 3000 feet high, is full of small sublimities which are impressive in the absence of larger. We may smile at Wordsworth's patriotic contention that Skiddaw is 'nobler far' than Parnassus, and 'pours forth streams more sweet than Castaly'; but however this may be, it is a fine bold specimen of the inferior mountains, and offers a view of much diversity, with the delightful little Derwentwater in the immediate neighbourhood, almost all the summits of the Lake District in the distance, and some Scotch hills across the Solway, not to mention the Isle of Man, and a possibility of seeing Ireland."[2]

"People," says Miss Martineau, "who made the ascent sixty years ago have left a terrifying account of its dangers, such as now excites a smile among energetic tourists. One gentleman was so 'astonished,' near the outlet, 'with the different appearance of objects in the valley beneath,' that he chose to stay behind. Another presently 'wished to lose blood and return,' but he was coaxed onward to the tarn,

[1] *Mem. Geol. Surv.*, Lake District. [2] Hamerton, *Landscape.*

where, however, he was surprised to find that he could see no stars, though it was noonday." [1]

Wenlock Edge (Fig. 92, p. 249) is one of the longest, sharpest, and straightest escarpments in South Britain, extending to a length of nearly 20 miles.[2] It is formed of Wenlock limestone and shale, belonging to the Silurian period.

The Quantock Hills, which extend for about 14 miles across West Somerset from Quantock Head in the north-west to West Monckton on the south-east, are a crumpled series of hard sandstones and slates of Devonian age.[3]

The western face is a steep escarpment, mostly covered with wood : the eastern slope is more gradual. Willsneck has a height of 1262 feet.

The Brecknock Beacon or Van, the loftiest mountain in South Wales, 2862 feet, is composed of Old Red Sandstone.

The rocks present a series of straight, nearly horizontal, lines, ending in steep slopes, and with a slight dip to the south.[4] As shown in Fig. 98, they are a good example of the carving out of a district by streams and subaerial action,—the summits are evidently not points which have been raised more than the rest, but those which have been denuded more slowly than, and consequently now project above, the surrounding area.

The Cheviots form the high ground which occupies

1 Miss Martineau, *Guide to the English Lakes.*
2 Murchison, *Silurian System.*
3 Etheridge, *Quar. Journ. Geol. Soc.* vol. xxiii. 1867.
4 Symonds, *Records of the Rocks.*

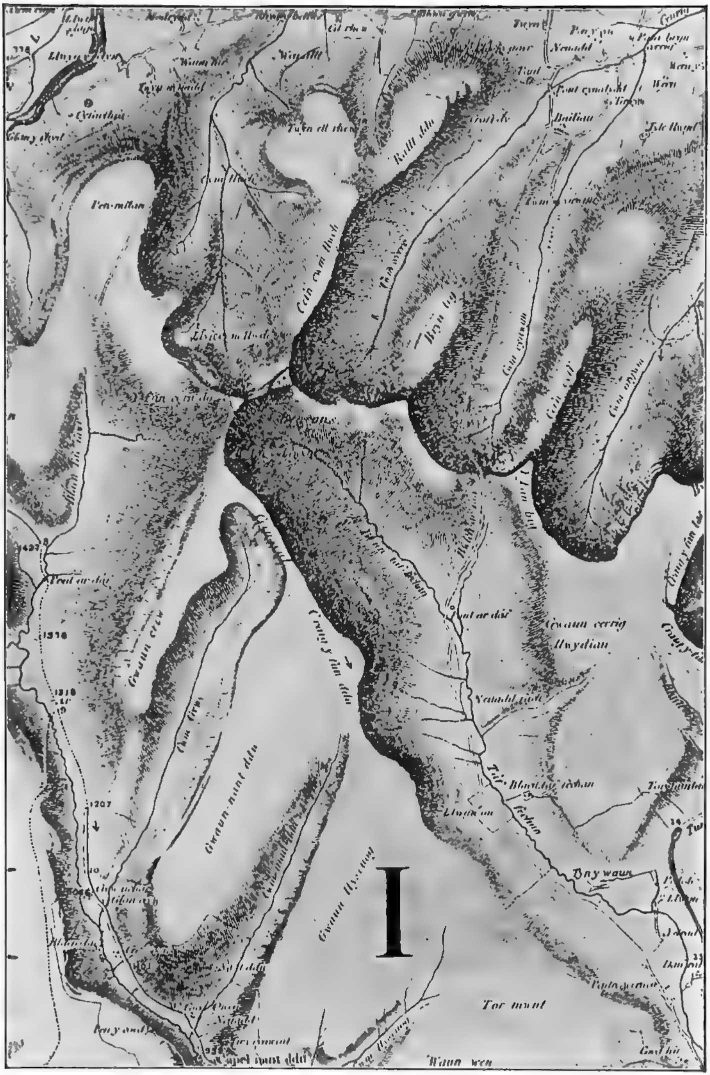


Fig. 98.—Map of the district round the Brecknock Beacon.

much of the borderland between England and Scotland. The highest points are the Cheviot, 2676 feet; Hedgehope, 2348; Comb Fell, 2132; Windy Gyle, 2034; Cushat Law, 2020; and Bloody Bush Edge, 2001.

They consist partly of lavas and tuffs and partly of Old Red Sandstone, lying on granite (peculiar as being almost the only British granite containing Augite[1]), and must therefore, like other granitic areas, have undergone a denudation of from 20,000 to perhaps 50,000 feet. The great northern glacier appears to have reached up to a height of about 1900 feet.

"The most rugged bit of mountain scenery in the district is, perhaps, the north side of Cheviot, particularly as seen from near the College Burn, a little below Southernknowe. The scars on the side of the Henhole, the deep glen high up on the west side of Cheviot, are also very fine."[2]

Sir W. Scott in *Rob Roy* says: "The Cheviots were before me in frowning majesty; not indeed with the sublime majesty of rock and cliff which characterises mountains of the primary class, but huge, round-headed, and clothed with a dark robe of russet, gaining by their extent and desolate appearance an influence upon the imagination, as a desert district possessing a character of its own."

Next in altitude to the mountains of North Wales and the Lake District come the summits of *The Pennines*—the nearest approach in our islands to a

[1] Teall, *Geol. Mag.* (Dec. 3), vol. i. 1884.
[2] Clough, *Mem. Geol. Sur.*, The Cheviot Hills.

mountain range. The highest summits are Cross Fell, 2892 feet; Mickle Fell, 2596; Whernside, 2414; Ingleborough, 2373; and Penyghent, 2270, etc. This range differs entirely in character from the mountainous districts already alluded to. It is, as will be seen from the accompanying figure (Fig. 99), an anticline or arch, sloping away gently to the east, and dipping abruptly on the west. It forms the backbone of Northern England, and is bounded on the west by the great Pennine fault already mentioned (p. 207), which gives rise on the east to a scarped

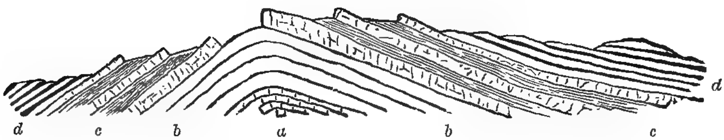


Fig. 99.—Diagrammatic section across the Pennine anticline. *a*, Carboniferous Limestone; *b*, Yoredale rocks; *c*, Millstone Grit; *d*, Coal-measures.

cliff (Fig. 81, p. 208), well seen from the Midland line between Settle and Carlisle,[1] while on the west it sinks gradually into the central plain of England.

The Pennines run north-west and south-east from the Cheviots, between Cumberland, Westmoreland, and Lancashire on the west; Northumberland, Durham, and Yorkshire on the east. Consequently, just as in the case of a house or a garden where there is a difference between different exposures, so also with this great natural wall there is a marked contrast between the comparatively sunny slope on

[1] Marr, *Scientific Study of Scenery*.

the south-west and the bleak moorlands on the north-east.

"Perhaps the whole world does not offer a spectacle more impressive to the eye of the geologist than that afforded by the contrast between the mighty wall of Mountain Limestone soaring to the height of two thousand five hundred feet above the vale of the Eden and the plain of Carlisle, and the level beds of the New Red Sandstone deposited in later times at the foot of the ancient escarpment, upon the relatively depressed portion of the same Mountain Limestone series." [1]

Phillips considered that the Pennines were elevated at the close of the Palæozoic and before the New Red.[2]

The elevation of the great ridge of the Pennines has separated the Coal-basin of Yorkshire on the east from that of Lancashire on the west. Originally, no doubt, they formed one area. Moreover, as we proceed northwards the dip on the west becomes gradually more accentuated, carrying the Coal-measures far below the surface, so that in the North of England there is only the eastern Coal-bed, that of Newcastle.

The height of Ingleborough (Fig. 100) is due to the hard Millstone Grit which forms the summit and crowns the mountain. Whernside and Penyghent are similarly constructed. The photograph of Penyghent (Fig. 101) shows the nearly horizontal beds of

[1] Phillips, *Geol. of Yorkshire*, vol. ii.

[2] See also Wilson, *Age of the Pennine Chain; Geol. Mag.* (Dec. 2), vol. vi. 1879.

grit; the slope below consists of perishable shales, standing on a platform of Carboniferous Limestone, the surface of which is fretted into deep furrows. These mountains are fragments left of strata which once covered the surrounding country, and show therefore how great the denudation has been.

The so-called "*Peak*" of Derbyshire (Fig. 102) is really a tableland attaining a height of about 2000 feet, more or less triangular in form, and constituted by an outlier of hard grit. It is indeed a "cup" rather

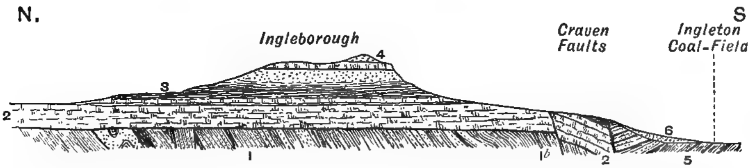


Fig. 100.—Section across Ingleborough (Goodchild). 6, New Red Breccias; 5, Coal-measures; 4, Millstone Grit; 3, Yoredale rocks; 2, Carboniferous Limestone; 1^b, Upper Cambrian or Ordovician rocks containing Bala fossils; 1, Older Cambrian rocks.

than a "peak," for it forms a flattened basin, the beds on all sides dipping into the hill. The pressure and consequent hardness thus produced has probably led to the preservation of this portion of the grit, which was no doubt originally continuous with the corresponding beds to the east and west. The edges form wild craggy cliffs, with deep river gorges winding far back into the heart of the plateau. The upper surface is covered by a considerable thickness of peat, through which, however, bosses of grit project, and have been worn into wild and fantastic forms. The largest group of these weathered rocks is at Edale Head. Many of these rocks are undercut by

Fig. 101.—Penyghent.

the sand driven by the high winds. The scenery is very wild and impressive, especially about the Downfall, when the stream after heavy rains falls over a high precipice of grit, round which fallen masses of the rock are strewn in wild profusion.[1]

Wen Hill, Brown Edge, and Crook Hill are other, but much smaller, outliers of the same grit.

The country round the Peak is a broad plateau of grit, known as "Pendle" grit, some 500 feet lower

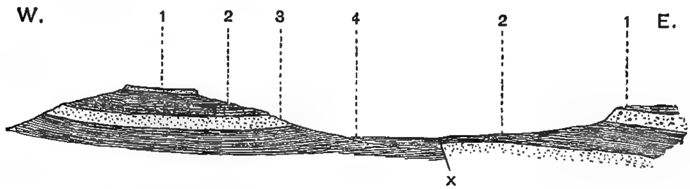


Fig. 102.—Section across the Peak of Derbyshire and the valley of the Derwent, near Chatsworth. 1, Kinder Scout Grit forming the Peak; 2, Shales; 3, Shale Grit; 4, Shales; x, Chatsworth Fault.

than that of the Peak itself, and deeply channelled by brooks and rivers.

The town of Buxton stands on Carboniferous Limestone, which is bounded on the west by a fault.

Mam Tor, or the Shivering Mountain, is so termed from the constant disintegration of the strata, especially towards the Castleton valley, and after rain and frost. On that side is a precipitous escarpment of shale and sandstone belonging to the Carboniferous period. On the north the slope is less steep, and grassy.

A great part of this hill, which rises 1300 feet above the valley, has fallen away, carrying with it

[1] Green, *Mem. Geol. Surv.*, North Derbyshire.

one side of an old Roman camp that formerly occupied its summit, and part of which can still be traced. In the fall it is said that fields, trees, and even cottages were overwhelmed.[1]

On the north, says the late Bishop of London, "the moorlands of the Peak made way for a fringe of woodland, which broadened into the Forest of Needwood, reaching to the valley of the Trent. Westward of this rose a bleak upland, known later as Cannock Chase, which stretched almost to the Forest of Arden."

This district is justly celebrated for its fine scenery. The Carboniferous Limestone, with its outlines generally smooth, its well-rounded grassy slopes, and deep narrow dales and ravines (Fig. 116, p. 295), presents a marked contrast to the wild moorlands and escarpments of the Millstone Grit. These narrow dales or gorges have sometimes a stream at the bottom, whilst at others the valley is quite dry, the water having found its way underground.

The Millstone Grit is so named because from the extreme hardness of some of the beds it has been much used for millstones, and the escarpments of this rock for the same reason stand out sharply and form some of the best known "Edges"—for instance, Axe Edge (Fig. 147, p. 339), Bamford Edge, Derwent Edge, etc.

Derwent Edge is a magnificent escarpment of the Kinder Scout or Peak bed of the Millstone Grit, crowned by many strangely-shaped piles of rock, and

[1] Mello, *Geol. of Derbyshire.*

generally ending in a cliff of gritstone, below which is a steep slope of the underlying shale.[1]

The Mendip Hills stretch from Frome to the Bristol Channel. The highest point, Black Down, attains a height of 1067 feet.

They consist mainly of Carboniferous Limestone, thrown into a series of folds, and sometimes highly inclined. In places the Old Red Sandstone has been exposed, which, though geologically lower, forms some of the highest ground. There are also some intrusions of volcanic rock, as for instance between Downhead and Beacon Hill.

In one place the Coal-measures are actually inverted, so that they are worked *under* Carboniferous Limestone, above which, of course, they normally lie.

In his Memoir on South Wales, Sir A. Ramsay has shown[2] that a mass of strata from 4000 to 6000 feet in thickness must have been denuded from the present highest point of the range.

In the lowlands to the west the celebrated Tor of Glastonbury is conspicuous (Fig. 103).

The beautiful gorge of Cheddar has no doubt been cut out by the stream, which now runs underground, and gushes out at the opening of the gorge. The popular idea that the gorge is due to a rent or violent disruption is entirely erroneous.

Exmoor (Dunkery Beacon, 1707) is also Devonian, but farther to the west the higher tracts are all of

[1] Green, *Mem. Geol. Surv.*, North Derbyshire.
[2] *Mem. Geol. Surv.* vol. i.

granite. Devon and Cornwall have four or five large, and several smaller, islands of granite rising out of a plain of Devonian slates,—Bodmin Moor, Brown Willy (1368), Hensbarrow Beacon district, that between Falmouth and Camborne, and lastly the Lands End. *Dartmoor* attains a height (Yes Tor) of 2050 feet. The granite probably everywhere underlies the slate, and the bosses which are detached at the surface are part of one general mass.

There have been two theories with reference to the Devon and Cornwall granites: one, that they

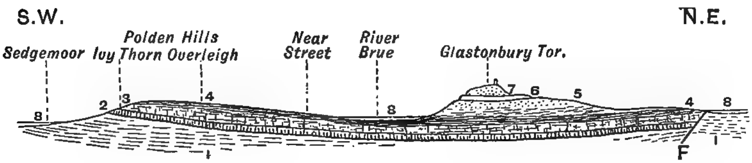


Fig. 103.—Section from Sedgemoor through Glastonbury Tor. 1, Keuper Beds; 2, Rhætic Beds; 3, Limestones, Lower Lias; 4, Clays; 5, Middle Lias; 6, Upper Lias; 7, Midford Sands; 8, Alluvium; F, Fault.

represent a line of eruptive rock at the base of volcanoes belonging perhaps to Permian times; the other, that they are masses of molten rock which forced apart the sedimentary strata, insinuating themselves between the Devonian and Carboniferous rocks, forming "laccolites" or great lenticular masses, which, however, did not rise to the surface. The two views might perhaps be reconciled by regarding them as reservoirs or local thickenings in the pipes. In any case, when the granite cooled and solidified, it must have been covered by many thousands of feet of strata, which have been subsequently removed by denudation. Rupert Jones

has suggested that the forms of the Tors have been to a great extent determined by the arrangement of the fissures and divisional planes which intersect the mass.

The metalliferous lodes to which Cornwall has owed so much of its wealth were perhaps formed at the roots of ancient mineral springs and geysers, which spouted their steam and water into the air, just as those of Iceland and of the Yellowstone Park do now. They probably belonged to the time when the volcanic forces of this interesting region were on the wane, and after the great lava-streams had been erupted.[1]

The Peckforton Hills are of no great altitude, but they have made a name for themselves because they stand out boldly to a height of some 500 feet above the lower ground around them. They form the highest level attained by the New Red (Triassic) Sandstone. Raw Head, so named from the whiteness of the rock by which it is crowned, rises to nearly 1000 feet. The range is bounded by, and indeed due to, a series of faults. On the east it is abruptly terminated by one which runs from north-north-east near Beeston Castle, south-south-west to beyond Malpas. Its position is marked along the whole district by the outburst of springs, from one of which the town of Malpas is abundantly supplied. At the northern extremity and on a platform of Sandstone belonging to the Trias (Lower Keuper) stands Peckforton Castle, commanding a fine view over the Cheshire plain, and looking to the northward across a deep valley; the rock of Beeston

[1] Hudleston, *Geol. Mag.* (Dec. 3), vol. vi. 1889.

Castle rising in a solitary mass from the surrounding plain, and crowned with ruins, forms a striking object.[1]

Alderley Edge is also an escarpment of Lower Keuper Sandstone. It rises with an abrupt and picturesque slope, to the west of which is a plain but slightly raised above the level of the sea, everywhere well wooded and well cultivated, while to the east are lofty hills with deep dells and wide valleys, between which the country is for the most part bleak and barren moorland. On the west the low hills are rounded, soft in outline, and dotted about irregularly; on the east are long unbroken ridges of terraced hills, which range for miles in more or less parallel lines.

At Kinver Edge, again, the top beds of the Trias are hardened by a calcareous cement, forming an escarpment looking over the west.[2]

The Cotteswolds run diagonally across the centre of England, from south-west to north-east. Speaking roughly, they separate the valley of the Thames from that of the Severn and the Ouse.

Seen from the west they form a very striking feature in the landscape, rising abruptly from the valley, and forming a bold escarpment due to hard Oolitic Limestone rocks, which lie on the comparatively soft strata of Lias. Fig. 104 gives a section from Leckhampton Hill to Burford.

The district east of the Severn consists of two portions, the upland and the plain—the Oolitic and

[1] Hull, *Mem. Geol. Surv.*, The Triassic Permian Rocks of the Midland Counties of England.

[2] Hull and Green, *Mem. Geol. Surv.*, Stockport, etc.

the Liassic, distinct in geological and physical structure. The tableland has an average height of 750 feet, rising, however, to more than 1000 (Broadway Hill 1040), and the dip to the east is about 1 in 130. The north-western margin of the Cotteswolds is indented by many ramifying valleys, generally narrow, often with precipitous sides, and extending their arms for miles into the upper region. Some of those valleys appear to have originated in faults.

It is evident that the Oolitic strata once extended

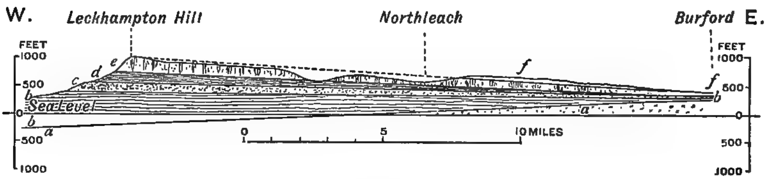


Fig. 104.—Diagram section from Leckhampton Hill to Burford. *a*, Keuper Marl, etc; *b*, Lower Lias; *c*, Middle Lias; *d*, Upper Lias; *e*, Inferior Oolite series; *f*, Great Oolite series.

far to the west of the present line of escarpment. On the Gloucester plain are several outliers standing up like islands above the level surface of the Lower Lias. The largest is Bredon Hill, which presents its most abrupt side to the north, from which the whole upper surface has a gentle slope to the south, till it reaches the level of the plain. On the south it terminates in a fault, which, by lowering the strata to the north, and thus rendering them for a time more protected than those of the surrounding area, has given rise to the hill. It may seem "at first sight a geological paradox that the district which has been

subjected to a vertical fall is that which now rises conspicuously above the plain."[1]

There are other outliers at Toddington, Dixton, Churchdown, Battledown, and Bowden Hills composed of Marlstone; Robinswood Hill, capped by inferior Oolite; Oxenton, and Dumbleton. These are all connected with, and partly due to, faults, which

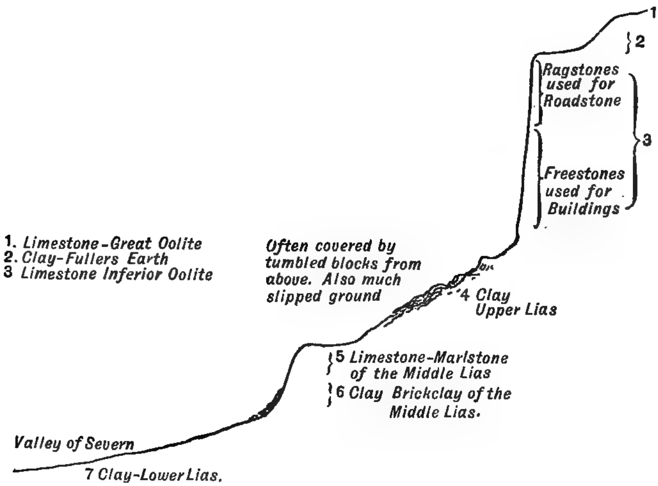


Fig. 105.—Section of the Cotteswolds at Birdlip.

have contributed to their preservation in a manner similar to that already mentioned in reference to Bredon Hill.

The escarpment looks from a distance like a single cliff, but on nearer inspection is more or less interrupted by a subsidiary ridge (Fig. 105), and sometimes by two. These are due to harder limestone bands. The summit consists of clay, slatey and calcareous beds, known to geologists as the "Great Oolite."

[1] Hull, *Mem. Geol. Surv.*, Cheltenham.

Farther to the north-east, however, in Rutland, there are two distinct escarpments, those of the Inferior Oolite and the Marlstone rock-bed, some miles apart.[1]

The various rocks forming the Oolite series do not, of course, maintain the same character everywhere; and as the steepest part of the escarpment is due to the hardest rock, it varies from place to place. In Yorkshire the Howardian Hills are formed by the Coralline beds; the Lincolnshire cliff is Inferior Oolite. At Edge Hill the Marlstone forms the steepest angle; along the Cotteswolds proper, at Cleeve Cloud (1093 feet) and Broadway Hill, the Inferior Oolite; near Bath the Great Oolite; and farther to the south-west the Forest Marble.

The Chilterns run approximately parallel to the Cotteswolds, and are the escarpment of the Chalk, as the Cotteswolds are that of the Oolites. Moreover, as the Oolites once extended to the west for an unknown distance over the Lias, so did the Chalk extend over the Oolite.

The North and South Downs (Fig. 106) are also Chalk escarpments, and surround the Weald.

The Weald is one of the best-defined geological areas in England. It is an oval-shaped area, a fertile and well-watered district bounded all round by a steep Chalk ridge, which runs from between Dover and Folkestone, by Maidstone, Sevenoaks, Westerham, and Reigate to Farnham, and round by Alton, Petersfield, Steyning, and Lewes to Beachy Head.

[1] Judd, *Mem. Geol. Surv.*, Rutland.

We owe our first correct ideas of this interesting district to Farey and Scrope. The memoir by the former is also interesting as having introduced the term "denudation," now so familiar, but which in its present application is not yet a century old, as it only dates back to 1806.

If we take six pieces of paper, bend them up in the middle, and snip off the top of the dome, we shall have six oval rings, one inside the other. This represents on a small scale the structure of the Weald. The six rings are represented by the Hastings Sands,

Fig. 106.—Section of the Weald of Kent. *a* and *a*, Upper Cretaceous strata, Chalk, forming the North and South Downs ; *b* and *b*, escarpment of Lower Greensand, with a valley between it and the Chalk ; *c* and *c*, Weald Clay, forming plains ; *d*, hills formed of Hastings Sand and Clay. The Chalk, etc., once spread across the country, as shown in the dotted lines.

the Weald Clay, the Lower Greensand, Gault, Upper Greensand, and Chalk. The Chalk escarpment forms the North and South Downs. The extreme south-eastern corner is in France. Some of the remainder of the eastern part—the region now occupied by the Straits of Dover—has been washed away by the sea.

The Lower Greensand also forms in places a bold escarpment, and on Hindhead Common rises to over 950 feet. Leith Hill, 965 feet, is the highest point in the south-east of England.

But while the district is thus clearly marked out by so striking a physical boundary, it is remarkable

that, as Topley points out,[1] it never, or scarcely ever, forms the boundary of any political or other division. Manors, parishes, registration districts, and parliamentary divisions alike ignore it.

The explanation of this I shall endeavour to show later on.

It is, of course, evident that before the elevation of the Weald took place, the Weald Clay extended over the Hastings Sands, the Lower Greensand over the Weald Clay, the Gault over the Lower Greensand, the Upper Greensand over the Gault, and the Chalk over the Upper Greensand.

The respective thicknesses of these strata are—

Chalk	1000 ft.
Upper Greensand . . .	80 ,,
Gault	100 ,,
Lower Greensand . . .	600 ,,
Weald Clay	750 ,,
Hastings Sands . . .	1000 ,,
	3530 ft.

In the centre of the district, therefore, say at Crowborough Beacon, where the Hastings Beds are at the surface, there must have been a denudation to the extent of, in round figures, some 2500 feet.

Hopkins applied to such an assumed height the term "geological elevation," to distinguish it from the actual relief of the surface, for it does not follow that the land ever rose to that height because denudation and elevation probably proceeded together.

[1] *Mem. Geol. Surv.*, The Weald.

The Tertiary strata do not attain to the dignity of mountains, though they form a certain number of hills which are celebrated, partly from their being near London, and partly because they rise to a height considerably above the neighbouring valleys: as, for instance, to the north of London, Hampstead and Highgate, and, to the south, Shooter's Hill and Well Hill. These consist mainly of gravel and sand.

CHAPTER IX

THE HISTORY OF A RIVER

The moisture drawn up by the heat of the sun from the surface of the seas and oceans, and wafted by the wind over the land, is eventually condensed and falls in the form of rain or dew, hail or snow.

If the soil be porous, the rain sinks into the ground and bursts out in springs lower down. If, on the contrary, the strata are impervious, the rain as soon as it has saturated the immediate surface begins to trickle off in a fine sheet or film. At first this film is very thin, its velocity is small, the friction is great in comparison, and it can move only the finest particles. Gradually, however, it gains volume and force, begins to collect into little rills, cuts into the grass and earth, and makes a shallow channel in the soil; joins with neighbouring rills and thus gathers strength,—for while the friction is proportional to the square root of the quantity of water, the energy is proportional to the product of the mass and the square of the velocity.[1] The circumstances vary so much that the problem is very complex. If V be the velocity, S the slope, and R the "hydraulic radius" (or say the

[1] Richthofen, *Führer f. Forschungsreisende.*

quantity of water), Chezy[1] deduced the formula $V = c\sqrt{RS}$. For English rivers c may, according to Downing,[2] be taken at about 100. Hence any addition to the volume of water, even if the fall remains the same, greatly increases the velocity and consequently the power of transport.

It is important to remember that in these statements other things are considered to be equal. For instance, much depends upon the character of the bed, and upon the depth. A given volume of water in a narrow channel is more effective than if spread over a wider surface.

As the energy exerted by a stream of water running down its valley depends on the inclination of the bed and the quantity of water, the velocity with any given inclination will depend on the quantity of water, while with any given quantity of water the velocity will depend on the inclination.

If there were no friction between the water and its channel, the velocity would continually increase. The friction, however, checks and often prevents any increase in speed. It is greater at the bottom and sides than in the centre and on the surface. Hence in a straight channel the velocity is greater in the middle than at the bottom or the sides, and is greater in floods than at other times. The inequalities in the motion thus produced induce currents and eddies more or less oblique to the general movement. The maximum velocity of a stream is a little below the surface, while the mean velocity is about four-fifths

[1] Vernon Harcourt, *Rivers and Canals.* [2] *Hydraulic Manual.*

of that at the surface, and twice that at the bottom. The actual proportions, however, depend on so many factors that no exact figures can be given.

A rate of 10 miles an hour is a rapid stream. The Ohio at Cincinnati, where the fall is 4 inches to the mile, has a mean surface speed of $1\frac{1}{8}$ mile per hour when the water is low, *i.e.* 6 feet deep, and nearly 6 miles an hour when it is high, *i.e.* 54 feet deep, the rate in the middle of the river being 6·35, and half way to the banks 5·85 miles per hour. The Thames runs at from 2 to 3 miles an hour; the Tay at Perth, 3 miles; the Tyne, from 1 to 2.[1]

The velocity of the surface water of the Rhine at Strasbourg has been found to be 1·5 metres in a second during low water, and 2·15 with an average water supply, rising to 2·85 in floods.

When engineering works are undertaken to facilitate navigation the slope may safely be reduced to 3 or 4, and should not if possible exceed 10, inches per mile.

If the resistance of any object lying in the stream is less than the force of the water, it is moved down until it meets some obstacle, or until it comes to a place where the slope of the bed reduces the velocity, and consequently the force, below the necessary momentum. When running water has taken up a certain quantity of earth, stones, etc., its energy is absorbed to some extent by the work of transport, and consequently the rapidity is diminished. Hence in the cases where peat-bogs burst or overflow (see p. 464), the water being charged with, or

[1] Stevenson, *Canal and River Engineering.*

almost changed into, mud, moves but slowly. The velocity may be said to be converted into work.

A velocity of 3 inches per second will move fine mud, of 6 inches per second fine sand, 8 inches will move sand as coarse as a pea, 12 inches will sweep along fine gravel as large as a bean, 24 inches will roll along rounded pebbles an inch diameter, and it requires 3 feet per second to sweep along angular stones of the size of a hen's egg.[1] It has been calculated that the scouring power increases as the sixth power of the velocity.[2]

Fragments of rock, however hard and angular, which are transported by water, gradually assume the form of gravel.

Daubrée made some interesting experiments on this point. He placed pieces of granite and quartz with water in a horizontal cylinder, to which he gave a movement of rotation of a metre in a second. After a movement equal to 16 miles, the angles were perfectly rounded, and the fragments could not be distinguished either in form or aspect from ordinary pebbles.

The power of rivers to excavate their valleys is much increased by the stones which they carry with them, and which concentrate the force of the stream on particular points, or at least on a smaller area. Hence a clear stream exercises much less erosive action than one containing or, so to say, armed with stones and gravel. They act as a sort of ammuni-

[1] Stevenson, *Canal and River Engineering*.
[2] Hopkins, *Quar. Jour. Geol. Soc.* vol. viii. 1852.

tion. They not only batter one another, but shatter and destroy the river-banks and the bottom of the stream. Colonel Greenwood, in his suggestive book on *Rain and Rivers* (1866), has happily compared a stream with and without boulders to a shotted and unshotted gun. We see a stream in its ordinary condition, and think it cannot possibly have excavated its valley; "but when the torrent is turbid with the wash of rain, we can hear its huge cannon-balls rattling down, and grinding each other and their rocky bed and banks, till what has started from the mountain's brow as a huge rock arrives at the sea in the form of pebbles or of sand." In such a case the boulders make a peculiar thumping noise, muffled as it were by the water.

It is not, however, only when swollen by floods that rivers excavate their valleys. Wherever the slope is sufficient the process is continually in operation. River water almost always contains fine particles of matter in suspension, though after passing through a lake these are reduced to a minimum, as, for instance, in the case of the Rhone at Geneva, and hence the beautiful blue of the water.

Besides the fine particles in suspension, there is also a certain quantity of matter dissolved in the water. This is especially the case with rivers which are derived from calcareous districts. The Thames, for instance, is estimated to carry down no less than 450,000 tons of salts in solution annually.

Mellard Reade has calculated from the data given in the Report of the Rivers Pollution Commission

that the rivers of England are now lowering the general surface of the country by about a foot in 12,000 years. In other cases the process is much more rapid, and has been estimated[1] in round numbers at—

For the	Danube area	one foot in	6800	years
,,	Mississippi	,,	6000	,,
,,	Ganges	,,	2400	,,
,,	Rhone	,,	1500	,,
,,	Hoang-ho	,,	1500	,,
,,	Po	,,	700	,,

Of course, it must be remembered that in the early

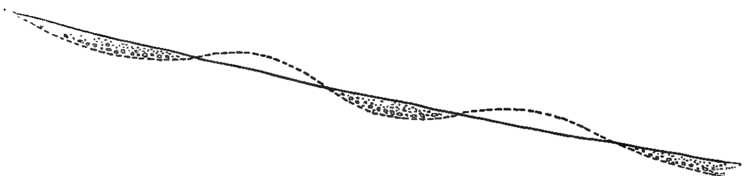


Fig. 107.—Diagram to show the Regularisation of a River-valley.

history of a river the lowering of the actual bed and its immediate neighbourhood will be most rapid, and that the rate will gradually fall.

It differs also greatly in different parts of the area. If the surface over which a river runs is irregular, being steeper in some parts than in others, it will have greater power on the steeper and less on the gentler slopes. It will therefore tend to remove material from the steeper parts and deposit it on those less inclined.

Hence a stream with an original bed such as that shown by the dotted line in Fig. 107 would tend to wear away the ridges and deposit firstly coarse

[1] Sir A. Geikie, *Geol. Mag.* vol. v. 1868.

gravel, then finer gravel, then sand, and finally mud, as shown by the diagram, and reduce the surface to a regular slope.

When at length a river has so adjusted its slope that it neither deepens its bed in the upper portion

Fig. 108.—The Regimen of a River.

of its course nor deposits materials, it is said to have acquired its "regimen" (Fig. 108), and in such a case the velocity will be uniform. The enlargement of the bed of a river is not, however, in proportion to the increase of its volume of water as it approaches the sea. Other things being equal, a river which increases in volume increases in velocity; and when

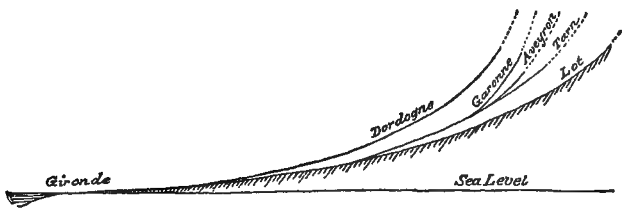


Fig. 109.—Slopes of the Garonne and its principal Affluents.

streams meet, the width of the combined river is generally less than those of the contributories combined. Any increase in the supply of water destroys the "regimen," and the river would again commence to eat out its bed. Hence, if rivers enlarge, as, for instance, owing to any increase in territory or greater rainfall, the slope diminishes. The above figure (Fig. 109) represents the profiles, and Fig. 110 gives a sketch-map, of the principal rivers in the

valley of the Garonne, and it will be seen that the larger the river the gentler is the slope. That of the lower Mississippi is only 2 to 3 inches to the mile;[1] of the Thames above Oxford 1·7 feet;[2] below, 1·5 feet.

If a stream has a superabundance of energy it will seize and carry down material, thus excavating its bed; if it is supplied with as heavy a load as it can carry, its energy is consumed and none is left for excavation.

Hence the course of most rivers may be divided

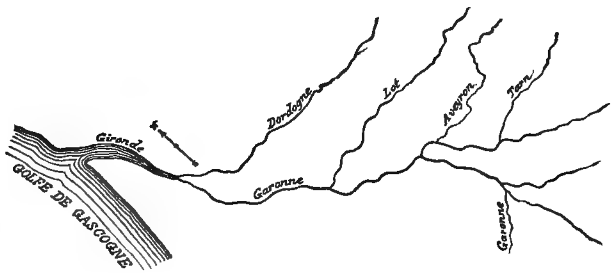


Fig. 110.—River System of the Garonne.

into three parts: (1) the torrent, where it is excavating; (2) the river, where it is neither excavating nor filling, but widening and levelling its valley; and (3) the delta, where it is depositing and filling up.

As a general rule it is the flood stage which determines the grade of the channel.

FIRST STAGE—THE TORRENT

In the first stage the stream has a surplus of force. It cuts deeper and deeper into its valley, carrying away the earth and stones to a lower level.

[1] Dana, *Manual of Geology*.
[2] Parker, "River Somme," *Proc. Geol. Ass.* vol. iv. 1875.

Fig. 111 shows the commencement of a stream on a hillside. A slight hollow has been excavated, scarcely, however, extending to the summit ridge.

Fig. 111.—Origin of a Stream.

Fig. 112 represents a stream—the Upper Dart—farther in its course, and when it has become a brook.

While the river is deepening its valley the weather is acting on the sides. Frost and rain disintegrate the surface, and if the strata are uniform the sides will assume a regular slope, the angle of which

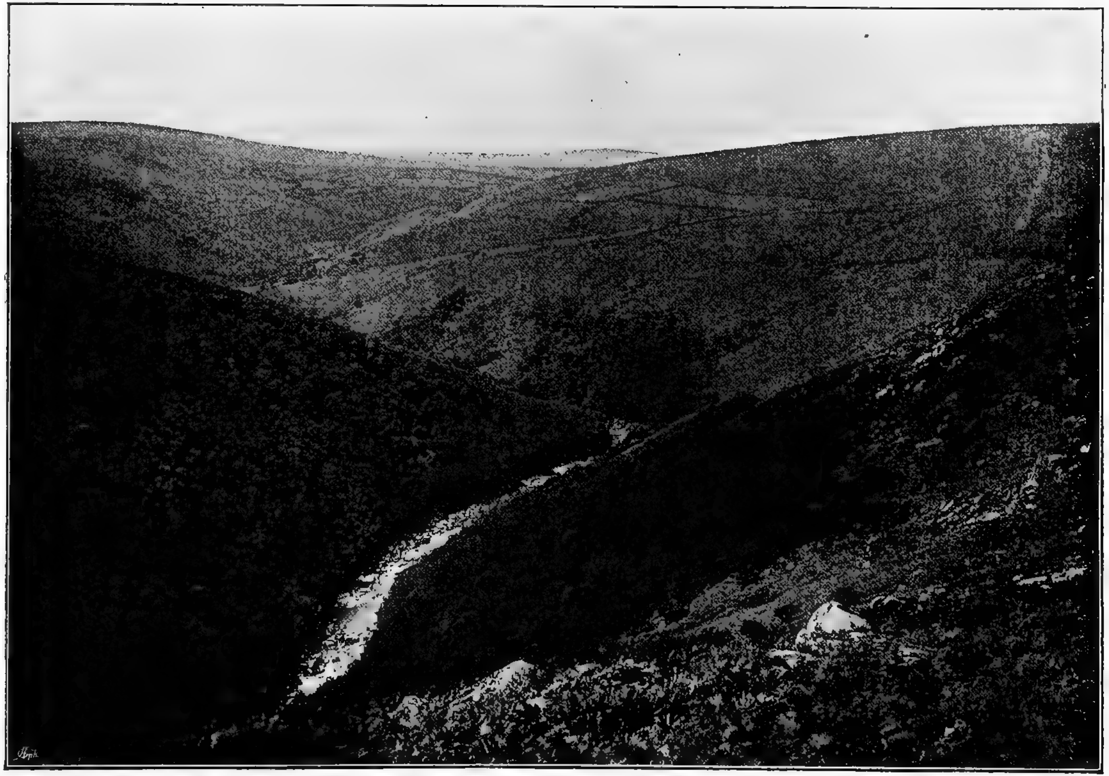


Fig. 112.—Upper Dart, from the moors.

will depend upon the character of the ground. As a general rule, the harder the rock the steeper the side; but this is not invariable. Climate and time must be allowed for; moreover, some hard rocks are much fissured or are liable to fracture easily, while others comparatively soft are able, in consequence of their toughness, to stand at a comparatively high angle.

If we suppose a valley with steep sides such as ABCD in Fig. 113, the steep face BC will give rise to a talus, which will assume a more or less gentle

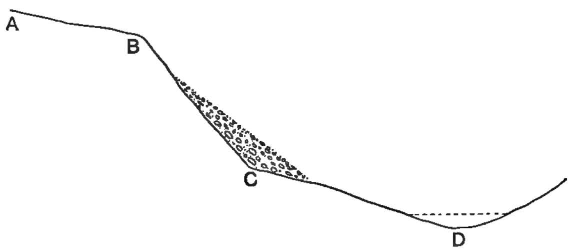


Fig. 113.—Side of a River-valley.

slope standing at what is known as the "angle of repose." The crest B gradually retreats, the edge wears away under the influence of the weather and is replaced by a convex curve, due to the action of the rain, which farther down, say at about C, meets the line CD, due to the action of the river, so that the side of the valley will tend to assume the slope shown in Fig. 114.

Hence the frequent cases in which our hills present a convex curve above and a concave curve at the base; and hence the Downs, due mainly to rain and weather, present their characteristic convex outlines.

The action of rain, worms, and frost in con-

tinually though slowly moving the soil and stones from higher to lower levels is indeed most important. Darwin[1] found that on a grass-covered slope with an inclination of $9\frac{1}{4}$ degrees, 2·4 cubic inches of earth annually crossed a line 1 yard in length. This may seem small, but when we bear in mind that most of the surface is more or less sloping, the whole effect must be great. In fact, the valleys would in this way be gradually filled up if the material were not carried away by rivers.

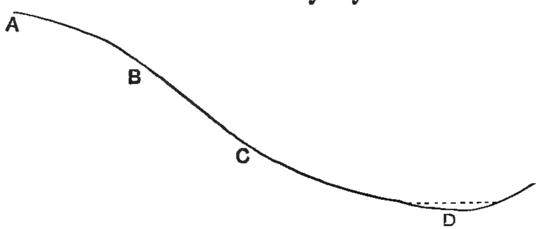


Fig. 114.—Slope of Fig. 113 at a later stage.

Large stones creep down the hillsides even more quickly. When heated by the sun they expand in the direction of least resistance—*i.e.* down the hill; and again when cooled at night their own weight makes them tend downwards.

This is the origin of the trains of great Sarsen stones—the rivers of stones, in some of our Wiltshire valleys.

Frost, again, has a great effect both in breaking up the surface of rocks, however hard, and in gradually moving the pieces downhill.

These changes all take time; and as the slope becomes gradually gentler and gentler, we may say

[1] "The Formation of Vegetable Mould through the action of Worms."

that, *cæteris paribus*, the shorter the time since the river attained its regimen, the steeper will the hill-sides be; and the older the valley the gentler the slopes of the sides; while for the same reason the slopes of the sides will be gentlest near the mouth and become steeper as we ascend the river.

The time required depends also greatly on the climate and on the character of the rock. Per-

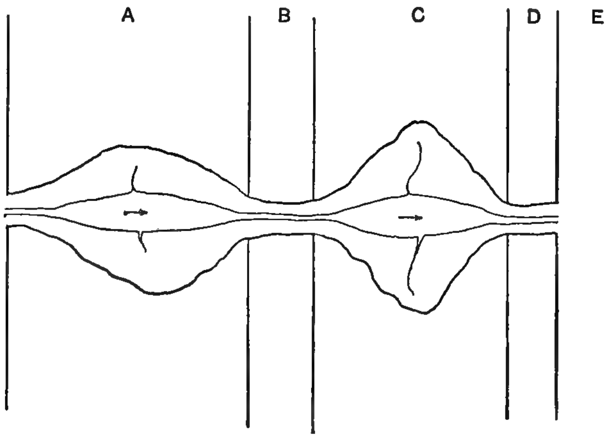


Fig. 115.—Diagram of a River-valley running across—A and C, soft strata; B and D, harder strata.

pendicular cliffs, such as those of the Colorado cañon, could not have maintained themselves in a moist climate such as ours: it is the absence of rain which has rendered them possible.

The valley will therefore be narrower (Fig. 115, B and D) where the rocks are hard and tough; broader, on the contrary (Fig. 115, A and C), where they crumble more easily into the stream under the action of the weather.

In many cases rivers run through gorges of great

depth, and yet very narrow, even in some places with overhanging walls. The Via Mala, which leads from the green meadows of Schams (Sexamniensis, from its six brooks) to Thusis, is about 5 miles in length, with a depth of nearly 500 metres, and very narrow, in one place not more than 9 to 15 metres in breadth.

The great cañon of the Colorado River, the gorges of the Aar, of the Görner, of the Tamina at Pfäffers, of the Trient, have a similar character. These were formerly supposed to be fissures due to upheaval. They none of them, however, present a trace of fracture; marks of water action can in places be seen from the base to the summit, and there can be no doubt that, as a rule, such gorges have been cut through by the rivers.

In certain cases, indeed, we have conclusive evidence. Some of them are left at times quite dry, and it is easy then to see that the rock is continuous from side to side. Again, the tunnels on the St. Gotthard line pass no less than six times under the Reuss, and there is no trace of a fault.

It may, I think, be said that the theory which attributed these gorges to splits in the rock is now definitely abandoned.

Of course, however, there are some cases in which the courses of streams have been determined by lines of fault and fracture.

The elevation of England above the sea being comparatively small, our larger rivers have in their lower parts passed through their first stage, though,

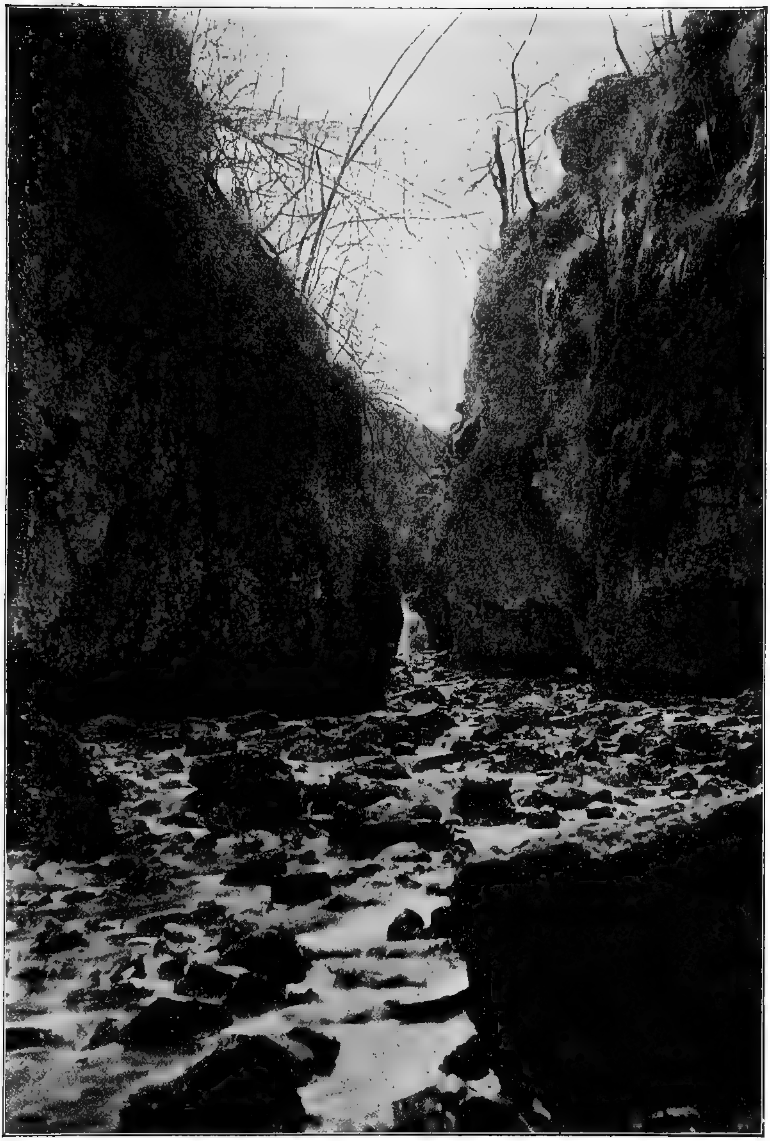


Fig. 116.—The Lovers' Leap, a gorge on a stream falling into the Wye near Buxton.

of course, innumerable examples occur among the smaller streams.

The gorge of the Avon at Bristol, the gorge of Cheddar, and many of the valleys in Carboniferous Limestone districts are cases in point. Fig. 116 represents the Lovers' Leap, a gorge on a small stream falling into the Wye just below Buxton.

SECOND STAGE

The second stage commences where the inclination becomes so slight that the river can scarcely carry away the loose material brought from above or showered down from the sides, but spreads it over the valley, in which it wanders from side to side, and which it tends continually to widen. The width of the valley depends on its age, on the size of the river, and the character of the rocks.

If we imagine a river commencing to run down a regularly inclined plane in a more or less straight line, any inequality or obstruction—the entrance of a side stream, a fallen tree, the eddies and currents induced by any sudden flood, or even the differences of velocity in different parts of the stream (see p. 282)—would tend to drive the water to one side or the other, and when once diverted it would continue in the new direction, until the force of gravity drawing the water downwards equalled that of the force tending to maintain its course in a straight line. The radius of the curve thus produced will follow a regular law

Fig. 117.—Curve on the Wye near Chepstow.

depending on the volume of water and the angle of inclination of the bed. Hence, though river curves commence in the first stage, they are more accentuated in, and therefore more characteristic of, the second.

Fig. 117 represents a bend on the River Wye at Chepstow, and Fig. 118 a view of the river from the so-called Precipice Walk at Dolgelly.

Among English rivers I may also refer, as instances, to the great bend of the Wear round Durham Cathedral, to the "crooks" of the Lune above Lancaster and Kirkby Lonsdale, and to the windings of the Thames.

De Lapparent gives[1] a different explanation of the cause of meanders, which he accounts for by saying that "la rivière, qui garde un excédant de force dans ses crues, cherche à réaliser son régime d'équilibre en augmentant la longueur de son parcours, par les sinuosités ou méandres qu'elle décrit au milieu des alluvions dont son lit majeur est tapiné." I confess I do not quite understand his view. No river, I think, ever attempts to prolong its course. It meanders against its will, and is always endeavouring to make short-cuts.

The exact conditions which regulate the meanders of rivers are not yet definitely determined, but we may say generally that the slighter the fall the greater the curves; if the fall is about 10 feet per mile, and the soil homogeneous, the curves would be so much extended that the course would appear

[1] *Leçons de Géographie Physique.*

Fig. 118.—View from the Precipice Walk at Dolgelly.

almost straight. With a fall of 1 foot per mile the length of the curve would be about six times the width of the river, so that a river 1000 feet wide would oscillate once in 6000 feet. This is an important consideration, and must always be borne in mind when it is attempted to make improvements in river courses; much labour has been lost in trying to prevent rivers from following their natural laws of oscillation. Rivers are very true to their own laws,

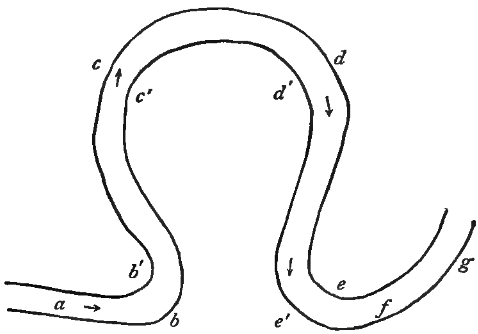


Fig. 119.—River Loop.

and a change in any part is continued both upwards and downward, so that a new oscillation in any place cuts its way through the whole course of the river both above and below.

Let us suppose a river *ag* (Fig. 119) meandering over a plain in the direction shown by the arrows and forming a loop.

The river strikes against and erodes the bank at *b*, forming a deeper channel, while it deposits gravel and sand at *b′*, forming shallower water and a shelving bank, so that a section across the valley would give some such outline as Fig. 120.

The current rebounding from *b*, would again strike the bank at *c*, where the same process would be repeated, only that the steep and shelving banks and the deep and shallow water will be on opposite sides of the stream. The ground between *c′* and *d′* will form a low plain sloping gently to the river. Such an arrangement may be seen at almost any bend of a winding river.

The contrast between the low shelving slope on the one side and the steep bank on the other is

Fig. 120.—Section of Valley at *b′b*.

Fig. 121.—Section of Valley at *c′c*.

shown in the following figure (Fig. 122) of Wadebridge, seen from the south.

The action of the river may be compared to that of a flat knife with a curved blade, or like a scythe cutting away the grass, leaving a wall of herbage on one side and a swathe of hay on the other.

When the river has eaten away a portion of the steep bank and commences to extend the "haugh," it will deposit coarse gravel in the lowest part, and over that gradually finer and finer materials. In such a case then, again, as in that already mentioned (ante, p. 286), we find, and it is indeed a general rule in river gravels, that the coarsest materials are at the bottom, and then become finer and finer upwards.

Fig. 122.—Wadebridge, seen from the south.

Gradually (Fig. 119) *b* and *e′* come nearer and nearer, until at length the river breaks through and rushes straight from *a* to *f*; only, however, to begin a new cycle of meanders, as the change causes the stream to impinge on the bank at *g*.

The laws relating to river curves do not apply to estuaries, where the current is alternately in opposite directions.

One result of these meanders is that we often find a hill left standing in the middle of a river-valley. Another result is that the loop often remains as a dead river-channel or "Mortlake." Such loop-lakes are known in America by the special name of "Oxbows." The whole process is sometimes very rapid. Rennell found that when the Ganges once begun to cut a bend the advance proceeded at the rate of a mile in ten or twelve years.

Such a neck is often cut through to shorten the river course in the interests of navigation. For instance, on the Tees a section was made which cut off a detour of 2½ miles, the navigation of which, moreover, was excessively intricate. In such cases, however, care must be taken that the inclination, and consequently the velocity, is not so much increased as to induce a current which would injure the banks.

The effect is to increase the velocity, to lower the level of the water above, raise it below, the cut. Such rapids, or "Lauffen," as they are termed in Germany, have often given names to towns, as, for instance, Lauffen on the Neckar, Lauffen on the Cher, Rhine, etc.

The Coquet in Northumberland has cut an alluvial curve through 80 yards in 18 years.[1]

The Germans have a useful term for the general course of a river, in distinction to these temporary and minor curves—namely the word "Thalweg."

Our maps often give an erroneous impression as to the courses of rivers, because the minor curves disguise the fact that the "Thalweg" consists of more or less straight lines, with sudden deflections almost at a right angle.

When the process has long continued, the curves may be sunk much below the level of the surrounding country. See, for instance, Fig. 123, representing the River Dart at Dittisham. To understand such sunk or "entrenched" curves we must carry our minds back to the time when the river ran at a much higher level.

Even under such circumstances the river will continue to wear away its banks, eat off the projecting angles, and thus broaden its valley, forming a river-plain, which will be more or less subject to floods after heavy rain.

During times of flood the velocity of the stream is checked when it overflows its banks; and the carrying force being thus diminished, some of the load is at once deposited. Hence in the middle part of their course many great rivers—the Nile, Mississippi, Po, etc.—run upon embankments (Fig. 124) which they have themselves formed.

[1] Miller, "On River Terracing," *Proc. Roy. Phys. Soc. Edin.* vol. vii. 1883.

Fig. 123.—River Dart at Dittisham.

The self-made banks of the Mississippi are 2 to 3 miles wide, with a fall of from 7 to 12 feet in the first mile, or more than ten times that of the river itself, and becoming gradually less as the distance from the river increases.[1] The Reno, the most dangerous of all the Apennine rivers, is in some places more than 30 feet above the adjoining country.

The Thames at and below London is artificially embanked, and much of the low-lying land is below high-water level.

One result is that large rivers often have marshes

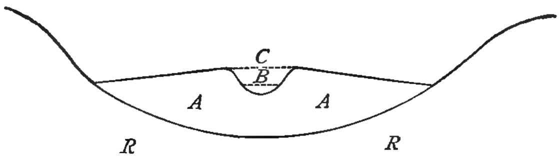


Fig. 124.—Diagrammatic section of a Valley (exaggerated). *RR*, sides of valley; *AA*, river deposits; *B*, ordinary level of river; *C*, flood level.

on one or both sides of their course, and the villages tend to be situated on the higher ground close to the river. In some cases the river splits, as it were, and sends a branch down each side of its own valley, as, for instance, the Windrush (Fig. 125) from Witney to near its junction with the Thames.

Another result is that tributaries often have a difficulty in reaching the main stream. They can neither ascend, nor work their way through, the river-bank. Hence they often run along the valley for a considerable distance parallel to the main stream until one of the great sweeps brings the river to the bluff on their side of the valley. The Yazoo,

[1] Credner, *Die Deltas.*

for instance, runs for some 180 miles along one side of the Mississippi valley till the great river annexes it, so to say, in one of its wide sweeps.[1]

Rivers under such conditions sooner or later break through their banks and, leaving their former bed, take a new course along the lowest part of their

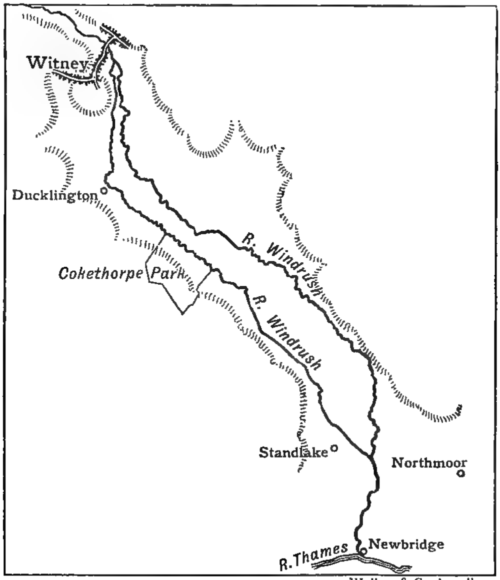


Fig. 125.—Bifurcation of the Windrush.

valley, which, again, they gradually raise. Thus they wander from time to time over the whole valley, so that no part can be raised much above the rest.

The larger rivers with which we are best acquainted, being more or less embanked and regulated, run under artificial conditions, but if left to nature every

[1] Davis, *Physical Geography.*

river may be said to have two channels—the ordinary river-bed and the flood-channel. Egypt is the flood-channel of the Nile; what we generally call the river is merely the low-water bed.

River-plains form the expanses of the Great Ouse valley over the Jurassic clays round Bedford, of the Yorkshire Ouse over the Trias of the Vale of York, and the Dee also over Triassic strata. Parts of London are built on terraces of Thames gravel.

THIRD STAGE

Finally, the river reaches a stage when the inclination becomes so small that it can no longer carry the load which it has brought down, even though the individual stones have greatly diminished in size. At first more or less angular, the rolling and clashing together has broken off all projecting angles, and worn them to the condition of pebbles and mud.

The coarse materials are deposited first, and only sand and mud reach the deltas. No gravel, for instance, reaches within 400 miles of the mouth of the Ganges,[1] and the deposits of the Nile in Egypt are entirely sand and mud.

Rivers differ extraordinarily in the quantity of mud, etc., they contain.[2] It has been estimated that the solid matter contained in 100,000 parts of water is in the Hoang-ho 500 parts, in the Tiber 456,

[1] Beardmore, *Manual of Hydrology.*
[2] Credner, *Die Deltas.*

Ganges 194, Nile 160, Mississippi 146, Rhone 50, Rhine 50, and in the Thames at Battersea only 3.

The materials which the river is unable to carry farther are deposited in a convex, fan-shaped cone or delta, and the greater the volume of water the gentler will the slope be, so that in great rivers it becomes almost imperceptible. On the other hand, in the cones formed where lateral mountain-streams enter a main valley the curvature of the cone is often very evident.

The materials slope in all directions, and the height will tend to be the same at all points equidistant from the apex of the cone. Hence if *a* (Fig. 126) be the apex of the cone, the points *bcde* will be equal in height;

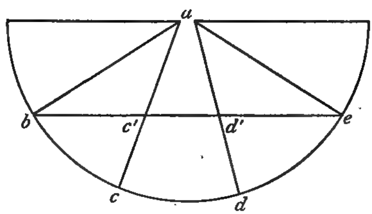


Fig. 126.—Plan of a Delta.

and if a line be drawn across from *b* to *e*, the line will be higher at *c′* and *d′* than at *b* and *e*. If the stream runs for a while along the line *ab*, it will gradually raise the level of its bed, and sooner or later the bank is broken through by the stream, which then switches itself off to a lower part of the cone, and it even occasionally happens that the two sides lead to different drainage systems. In course of time the whole cone is more or less raised, and in the deltas of great rivers the change from one channel to another sometimes leads to disastrous floods, as, for instance, in the valley of the Hoang-ho.

Though the materials are often very coarse, the general slope of the cone is very regular, so that they form apparently straight lines (Fig. 128) in the scenery, offering a remarkable contrast to the curves and irregularities of the surface elsewhere. When, as often happens, the main stream cuts away

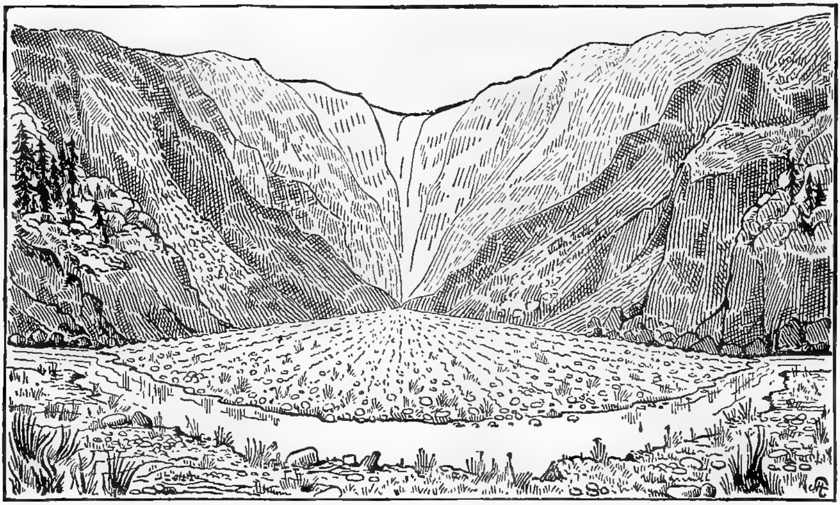


Fig. 127.—Diagram of a Mountain Valley, showing a River-cone. Front view.

part of the margin of the cone, and thus forms a bank, the lateral stream rushes over the edge, cuts a gully, and commences a second and lower cone. This process may happen more than once, and Drew figures[1] such a succession of three cones one over the other.

A side stream, with its terminal cone, when seen from the opposite side of the valley, presents the appearance shown in Fig. 127; or, if we are looking

[1] *Quart. Journ. Geol. Soc.* vol. xxix. 1873.

down the valley, as in Fig. 128, the river being often driven across to the other side of the main valley (Fig. 133).

Cones and deltas above and below water are often spoken of as if they were identical. No doubt under ordinary circumstances the surface and slope

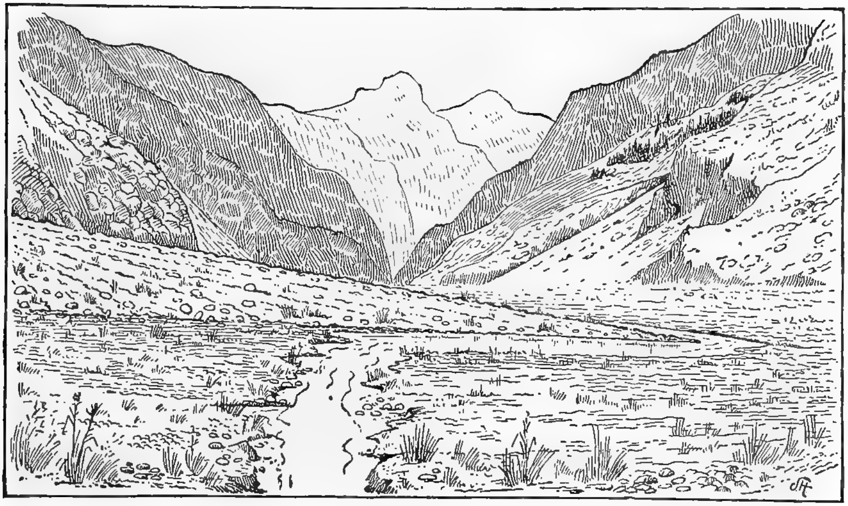


Fig. 128.—Diagram of a Mountain Valley, showing a River-cone. Lateral view.

of a delta formed under water will be the same as those of a cone formed in the air.

When, however, a fairly rapid river runs into deep water, the materials brought down fall into three well-marked divisions.

Before reaching the water the stream-deposits form (Fig. 129, a) gently inclined layers; but as soon as the water's edge (bb) is reached the coarser gravel rolls downwards, forming a steeper slope of 30° to 35° (c), beyond which again fine mud (d) is deposited. As

the stream gradually builds out its delta into the lake, this mud is covered over by layer after layer of gravel (*c*), so that finally we have gently inclined layers above, then gravel-beds at a high angle, and at base a nearly horizontal bed of mud or silt.[1]

Most of our streams have formed deltas where they fall into lakes (Fig. 130); and as most of our large lakes lie in hollows formed in the course of a river-

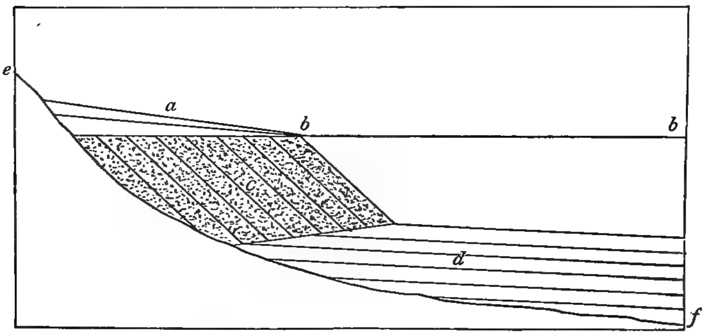


Fig. 129.—Diagram of a Delta.

valley, and have a river falling into the head of the lake, as for instance in the case of Windermere (Fig. 186, p. 411; see also Fig. 184, p. 407), etc., they have a delta at the upper end. In many cases, of course, as for instance in Ullswater, there are deltas in other parts of the lake which may be—in some cases almost, as for instance Haweswater, in others quite—bisected by the deltas of lateral streams. These cases will, however, be dealt with when we consider lakes.

The slope of deltas forms an angle of as much as

[1] See Gilbert, "Lake Shores," *U.S. Geol. Surv. 5th Ann. Rept.* 1884.

35° in the cone or talus of certain mountain streams, but in that of great rivers it is so slight that to the eye they appear quite flat.

The delta of the Danube has a slope of about 5 inches per mile; but in consequence of the course not being straight, the fall of the river is only about

Fig. 130.—Delta of the Aira Beck, in Lake Ullswater.

3 inches, with a velocity of $2\frac{1}{2}$ miles an hour in ordinary summer floods. When the water is low the fall is $1\frac{1}{2}$ inches per mile and the velocity 1 mile an hour.[1] The formation of deltas was well described by Herodotus.

"The greater part of Egypt," he said,[2] "as the priests informed me, and as appeared to me also to be the case, has been acquired by the Egyptians. For

[1] Beardmore, *Manual of Hydrology.*
[2] *Euterpe.*

the space between the above-mentioned mountains, that are situate beyond the city of Memphis, seemed to me to have been formerly a bay of the sea; as is the case also with the parts about Ilium, Teuthrania, Ephesus, and the plain of the Mæander, if I may be permitted to compare small things with great; for of the rivers that have thrown up the soil that forms these countries, not one can justly be brought into comparison, as to size, with any one of the five mouths of the Nile."

A considerable part of Norfolk is a low plain intersected by a network of rivers—the Bure, the Yare, the Ant, the Waveney, etc.—which do not rush on with the haste of some rivers, or the stately flow of others which are steadily set to reach the sea, but rather seem like rivers wandering about the meadows on a holiday. They have often no natural banks, but are bounded by dense growths of tall grasses, bulrushes, reeds, and sedges, interspersed with the spires of the purple loosestrife, willow-herb, hemp-agrimony, and other flowers, while the fields are very low and protected by banks, so that the red cattle appear to be grazing below the level of the water; and as the rivers take most unexpected turns, the sailing-boats often seem (Fig. 187, p. 415) as if they were in the middle of the fields.

Fig. 131 represents the delta of the Po, and it will be observed that Adria, once a great port, and from which the Adriatic was named, is now more than 20 miles from the sea. Perhaps the most remarkable case is that of the Mississippi (Fig. 132), the mouths

of which project into the sea like a hand, or like the petals of a flower. For miles the mud is too soft to support trees, but is covered by sedges (*Miegea*); the banks of mud gradually become too soft and mobile even for them. The pilots who navigate ships up the

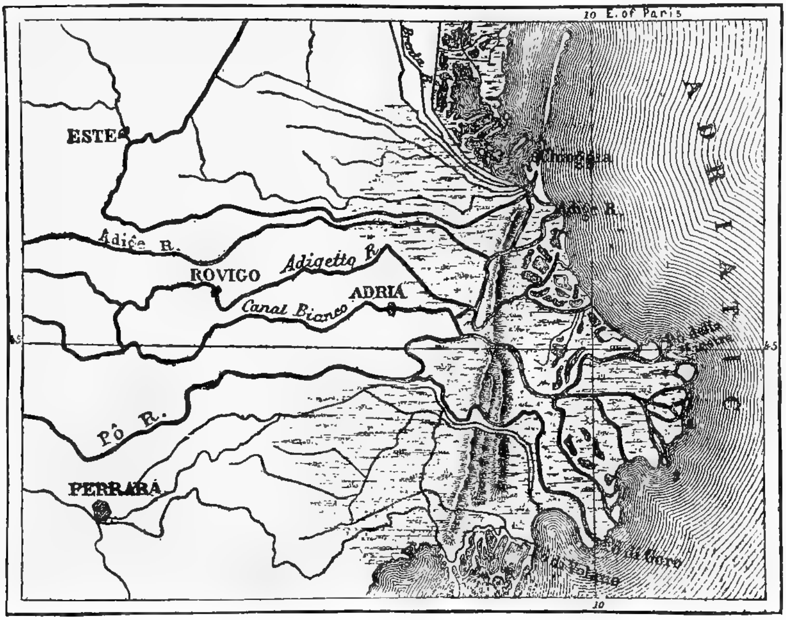


Fig. 131.—Delta of the Po.

river live in frail houses resting on planks and kept in place by anchors. Still farther, and the banks of the Mississippi, if banks they can be called, are mere strips of reddish mud, intersected from time to time by transverse streams of water, which gradually separate them into patches. These become more and more liquid, until the land, river, and sea merge imperceptibly into one another. The river is so

muddy that it might almost be called land, and the mud so saturated by water that it might well be called sea, so that one can hardly say whether a given

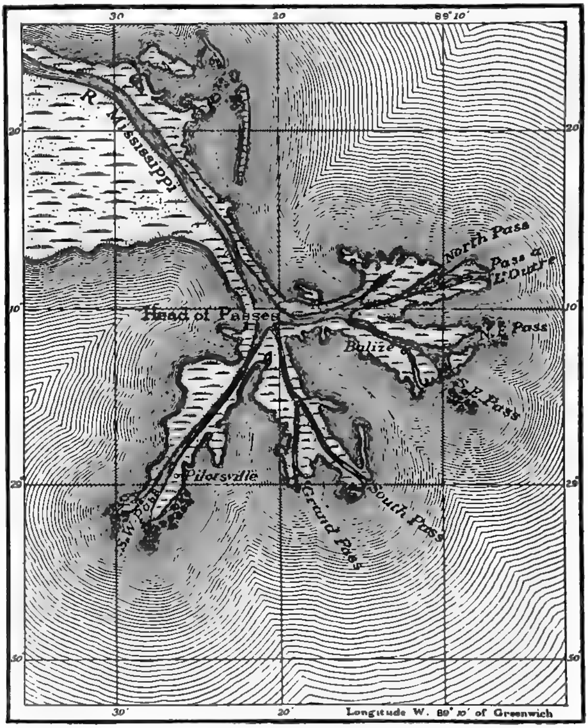


Fig. 132.—Delta of the Mississippi.

spot is on the continent, in the river, or on the open ocean.

Rivers falling into lakes almost always show a well-marked delta. On the other hand, those opening into the sea may be divided into two classes—those with estuaries and those with deltas. I have already (ante, p. 124) suggested why it is that while the

rivers flowing into the Mediterranean generally have deltas, our great rivers on the contrary—the Clyde and the Solway, the Ribble and the Dee, the Severn and the Solent, the Thames and the Humber, the Forth and the Tay—open into estuaries.

The estuaries, however, would long ago have been filled up by the rivers if it had not been for the tides.

When a river meets the sea the current is of course arrested, and the consequence is that the solid matters are deposited, forming the bar which occurs at the mouth of so many rivers, and is so great an impediment to navigation. Round our coasts, however, the materials are to a great extent carried away by the tidal wave, to which in this and other ways our commercial prosperity is so largely due.

But though tides have a tendency to prevent the formation of deltas, they are not in all cases able to prevent it. At the mouth of the Hoang-ho the tides rise 8 feet; at the Ganges-Brahmaputra, 16.

It is not unusual to cite deep valleys as evidence of long-continued river action, but in truth they represent only a stage in the process; as a matter of fact, it is rather the great plains which are the evidence and result of immense denudation.[1] The action of rain and rivers will, in the long-run, wear down any land-surface, whatever its original form may have been, to a flat plain, with a very gentle inclination to the sea-level. The valleys are first

[1] American geographers use the term "base level" as denoting "the lowest slope to which rivers can reduce a land area. With one margin it touches the sea, from which it rises imperceptibly" (Willis, *Nat. Geog. Monograph*, vol. i.). This, however, seems rather a misleading application of the term.

formed and brought to a gentle slope, then they are widened by degrees, and the higher ground is gradually worn down. The hardest rocks last longest, so that the first results are to accentuate differences and to create differences of level even where none at first existed; by degrees, however, the projecting points are themselves reduced—even the hardest rocks must yield in the end, and all are brought down to a dead level at last. The time required is of course enormous, and it seems often, if not generally, to have happened that fresh changes of level have occurred before the final condition has been attained.

When a lateral stream falls into a river the effects are by no means simple.

In the first place, it tends to drive the current against the opposite bank, and thus to modify the curves made by the river. Moreover, a change in one place gradually affects the course of the river, not only below, but above also.

Fig. 133 shows the deflection of the Rhone near Sion by the Borgne. In this case, however, the depth of the valley prevents any permanent change being effected in the course of the river. It is merely driven to the opposite side of the valley. In a flatter country the subsequent direction of the river might be permanently affected.

If the two rivers are equal, the combined stream will tend to follow an intermediate course, according to the laws of the composition of forces.

Again, when two streams meet, especially if they do so at an obtuse angle, the currents will be checked, and

hence gravel will be deposited in the angle between them, forming a tongue of land, varying in form and size according to circumstances, but tending to move the point of junction downwards.

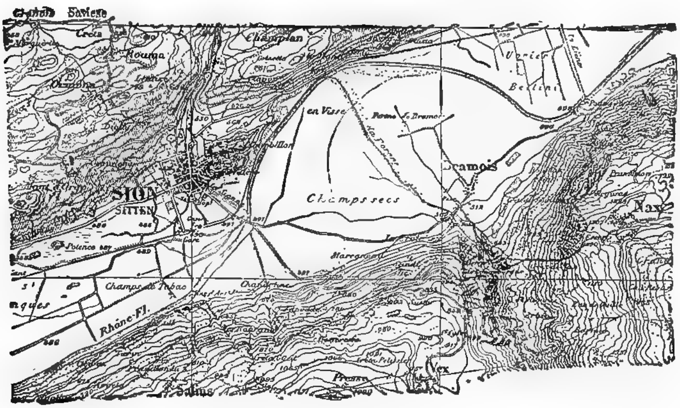


Fig. 133.—Valley of the Rhone at Sion.

FLOODS

Another point brought out by the study of rivers is that, just as in Geology, though there have no doubt been tremendous cataclysms, still the main changes have been due to the continuous action of existing causes, so also in the case of rivers, however important the effects due to floods, still the configuration of river-valleys is greatly due to the steady and regular flow of the water.

Floods may be divided into two classes: (1) those due to the bursting of some upper reservoir, such, for instance, as the great flood of the Dranse de Bagnes in 1818, due to the outburst of the lake, which had been dammed back by the glacier of Giétroz, or the

more recent flood of St. Gervais, owing to the bursting of a subglacial reservoir in the Glacier de Tête Rousse, which rushed down the valley in the dead of the night, in a few minutes swept away the Baths, and drowned most of the visitors; and (2) those due to heavy rains.

Almost every winter the lower parts of our river-valleys would be under water but for the embankments by which they are protected. After heavy rains the rivers rise far above their usual level. One of the most remarkable cases is that of the Moray floods of 1829, described by Sir T. Dick Lauder.[1] No less than $3\frac{3}{4}$ inches of rain fell in twenty-four hours; some of the streams rose 50 feet above the ordinary level; great numbers of animals —wild as well as tame—were drowned; bridges, houses, and fields were washed away; the rivers in many places changed their courses, and great masses of masonry and rock were washed for considerable distances. Sir T. Dick Lauder especially mentions one great mass of basaltic rock 8 feet long, 5 wide, and 4 high, which was carried down for over 300 yards.

These floods often rise with great rapidity, and hence the numerous remains of elephants, oxen, and other animals found in our river gravels.

Thus, then, I have endeavoured to give some idea of the course of a river from its source on the mountain to its mouth in the sea.

Summing up this chapter, we may say that as soon

[1] *The Great Floods of Moray*, 1830.

as any tract of land rose out of the sea, the rain which fell on the surface would trickle downwards in a thousand rills, forming pools here and there, and the water gradually collecting into larger and larger streams would, wherever the slope was sufficient, begin cutting into the soil and carrying it off towards the sea. This action would, of course, differ in rapidity according to the slope and hardness of the ground. The character of the valley would depend greatly on the nature of the strata, being narrow where they were hard and tough; broader, on the contrary, where they were soft, so that they crumbled readily into the stream, or where they were easily split by the weather. Gradually the stream would eat into its bed, reducing it to a certain slope, the steepness of which would depend on the volume of water. The erosive action would then cease, but the weathering of the sides and consequent widening would continue, and the river would wander from one part of the valley to another, spreading out the materials, and forming a river-plain. At length, as the rapidity still further diminished, it would no longer have sufficient power even to carry off the materials brought down. It would form therefore a cone or delta, and instead of wandering would tend to divide into different branches.

When we look at some great valley and the comparatively small river which flows through it, we may deem it almost impossible that so great an effect can be due to so small a cause. We find, however, every gradation from the little gully cut out by the last summer shower up to the great

cañon of Colorado. It is astonishing, as R. L. Stevenson says, "what a river can do, and all by following gravity in the innocence of its heart." We have to consider not only the flow of the water, but the lapse of time, and remember that our river-valleys are the work of ages. Moreover, even without postulating any greater rainfall in former times, we must bear in mind that we are now looking at rivers which have attained, or are approaching, their equilibrium; they are comparatively steady, and even aged; so that we cannot measure their present effect by that which they produced when they possessed the energy and impetuosity of youth.

From this point of view the upper part of a river-valley is peculiarly interesting. It is a beautiful and instructive miniature. The water forms a sort of small-meshed net of tiny runnels. We surprise the river at its very commencement: we can find streamlets and valleys in every stage; a quartz pebble may divert a tiny stream, as a mountain does a great river; we find springs and torrents, river-terraces and waterfalls, lakes and deltas, in the space of a few square yards, and changes pass under our eyes which on a larger scale require thousands of years.

And as we watch some tiny rivulet, swelling gradually into a little brook, joined by others from time to time, growing to a larger and larger torrent, then to a stream, and finally to a great river, it is impossible to resist the conclusion gradually forced upon us, that, incredible as it must at first sight appear, even the greatest river valleys and plains,

and the general configuration of the land, though their origin may be due to the initial form of the surface, are due mainly to the action of rain and rivers.

Note.—Throughout Western Europe a large proportion of the river names fall into three groups :—

From the Celtic *uisge* or *oich* (water), Latin *aqua*, Old German *aha*, softened into the French *eau*, we have the Aa, Awe, Au, Avon, Aue, Ouse, Oise, Oich, Ock, Aach, Esk, Usk, Uisk, etc.

From the Celtic *dwr* (Greek ὕδωρ), we have Oder, Adur, Thur, Dora, Douro, Doire, Durance, Dranse, Doveria, etc.

From the Celtic *rhin*, or *rhedu*, to run (Greek ῥέω), we have the Rhine, Rhone, Reuss, Reno, Rye, Ray, Raz, etc.

CHAPTER X

RIVERS—(*continued*)

After these general remarks, let us now consider certain special, but frequently recurring, circumstances which affect the courses of rivers. It is of course impossible within my limits to consider all the innumerable differences which may arise; but there are some which recur over and over again, and as to which some general observations may be made.

RIVER-TERRACES

The banks of rivers often present one or more terraces. These are of two kinds, weather terraces and erosion terraces.

If the valley is cut through a single uniform stratum, the slope of the side from top to bottom will be uniform. If, however, as very frequently, and in our country generally, happens, the sides consist of beds of different degrees of durability, the softer strata will yield more rapidly and form gentle slopes, while the more durable rocks will stand out as cliffs.

Fig. 134 shows some terraces in the valley of the

Bienne (Jura) due to the presence of hard calcareous layers.

These "weather" terraces must not be confused with the "erosion" terraces, which will be described later on.

In weather terraces, as the angle will depend on the hardness of the stratum, the width of the terrace

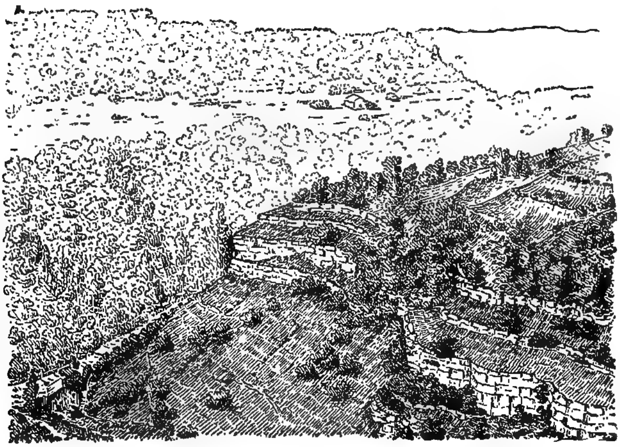


Fig. 134.—Weather Terraces in the Valley of the Bienne (Jura).

will depend on the thickness of the layer to which it is due.

In order, however, that the difference of hardness may exercise its full influence, a certain time is required. Hence in a newly formed slope the contrast between hard and soft strata is not fully shown. It gradually arrives at a maximum. After this, as even the hardest rocks give way in time, the difference decreases, until finally all the strata would be reduced to the same slope. Thus, then, the difference

increases for a certain time till it reaches a maximum, and then gradually diminishes again.

The second type of river-terrace has a very different origin.

Let us suppose a valley in which the river has attained its regimen. The materials are spread over the whole width of the valley, forming a plain with a very slight inclination towards the sea. They may form a comparatively thin layer, or the valley may have been excavated to a considerable depth, and then more or less filled up with sediment.

On such river-plains a double process is in operation. Floods scour out the bed of the stream, and thus lower the water-level. On the other hand, along the sides of the stream inundations deposit mud and silt, the flow being checked by the vegetation, and thus tend to slowly raise the level.

Now, let us suppose that the force of the river is increased relatively to the material brought down, either (1) by a fresh elevation; (2) by an increase of volume owing to an addition of territory, by a more copious rainfall, or locally by the removal of a barrier; or (3) that the work it has to do is diminished by any falling off in the supply of material to be carried down, so that the energy of the stream would be partly diverted from the work of transport to that of excavation;—it will then again cut into its own bed, deepening the valley, and giving rise to a rapid, which will creep gradually up the valley, receding of course more rapidly when the strata are soft, and lingering longer at any harder ridge.

The deepened river-valley cut into the old plain will not, at first at any rate, be so wide as the old one, so that a terrace will be left on one side, or perhaps on both. Such old river-terraces may be traced in most valleys; often indeed several, one above another. It has been sometimes supposed that these terraces indicate a greater volume of water in ancient times,—sufficient indeed to fill up the whole

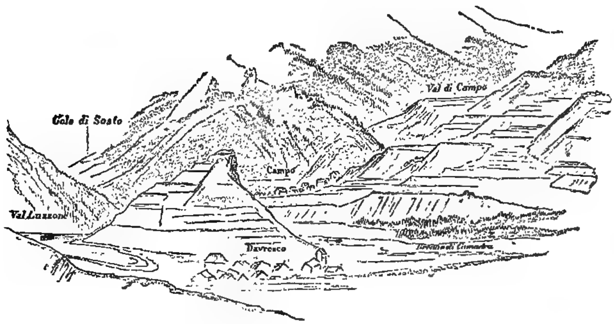


Fig. 135.—River-terraces in Val Camadra.

valley to the level of the upper terrace. It must, however, be remembered that the terrace was formed before the deeper part of the valley was excavated.

Fig. 135 represents a remarkable group of such terraces in the Val Camadra in Switzerland.

River-terraces are not perhaps so conspicuous in our country as in some others. They are well marked, however, on the banks of the Nidd between Knaresborough and Cowthorp, on the Skell near Ripon, in the Vale of Ripley, in Wharfedale near Boston Spa,[1] and elsewhere.

[1] Davis and Lees, *West Yorkshire.*

RAPIDS AND WATERFALLS

We often, as we ascend a river, after passing along a comparatively flat plain, find ourselves in a narrow defile, down which the water rushes in an impetuous torrent, but at the summit of which, to our surprise, we find another broad flat expanse. This is especially the case with rivers running in a transverse valley—that is to say, in a valley lying at right angles to the "strike" (see p. 187); the water acts more effectively where it runs across rocks. These differ greatly in hardness. The softer strata are of course eroded more rapidly than the harder ones; each ridge of harder rock will therefore form a dam and give rise to a rapid or cataract. In cases such as these each section of the river has for a time a "regimen" of its own.

John Phillips long ago called attention to such cases.[1] "We frequently see," he says, "that at some point above the contracted passage the country has the aspect of a drained ancient lake, as if, in fact, the passage had been forced by a large body of water which had been gathered above. Not unfrequently, indeed, the appearance of a lake is renewed by occasional floods of the river."

Mackintosh remarks that "in East Devon the River Dart (tidal $10\frac{1}{2}$ miles inland), when viewed from a hill at Sharpham, presents the aspect of ten distinct sheets of water, apparently isolated, arising from a succession of basins and connecting channels."

[1] *Valley of the Thames.*

The Connecticut River is divided into twenty-two distinct basins.

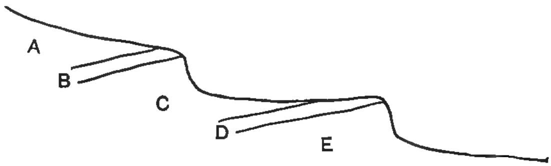


Fig. 136.—Section of a River-slope, showing hard (B and D) and soft (A, C, and E) strata.

In fact, wherever there are hard and soft strata forming terraces in the valley sides, similar differences will generally occur in the bed of the stream.

In such a case the stream will act more rapidly on

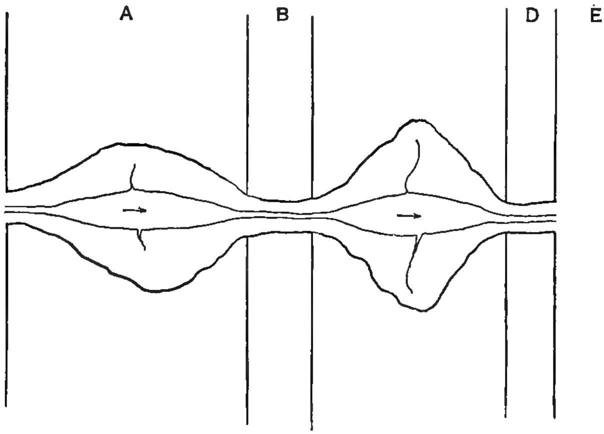


Fig. 137.—Diagram of a River-valley running across—A and C, soft strata; B and D, harder strata.

the softer strata, while the more durable rocks will be less affected. Suppose, for instance, a stream (Fig. 137) running across two hard strata B, D, between three softer ones A, C, E. It is evident that the latter will be more rapidly acted on by the stream. The durable strata B and D will act for a time as

Fig. 138.—Skelwith Foss.

base-lines, and above them the stream will form an alluvial plain, while where the stream comes to the hard strata it will form a rapid or waterfall, so that there will be a drop in the level where the stream passes from B to C and from D to E, and a plan of the valley represented in Fig. 136 would resemble Fig. 137. The banks of the stream as it passes through A, C, and E will have a gentle slope (Fig. 136), while in B and D the valley will be narrower and the banks steeper, or even perpendicular. Hence a section across the valley at A or C would resemble a flat saucer (Fig. 139), while

Fig. 139.—Section of Valley at either A or C.

Fig. 140.—Section of Valley at either B or D.

a section at B or D would take the form of a U or a V (Fig. 140).

Every barrier constitutes a base-line for the reach of river immediately above it, and leads to the formation of a river-plain, as the wide valley will be under water during floods, the result of which will be that fine mud will be deposited, especially in the depressions, and that any projecting portions will be sapped and lowered. Such plains in some cases were no doubt the sites of ancient lakes, but it is evident that river action would be sufficient to level the ground.

Fig. 138 represents Skelwith Foss on the Brathay above Windermere, where the water rushes through a narrow rocky gorge, above which the valley widens

Fig 141 —Langdale Valley. The Langdale Pikes are seen in the distance.

out again into a broad plain (Fig. 141), which was once evidently a lake.

Fig. 142 represents a similar gorge in Langstrath.

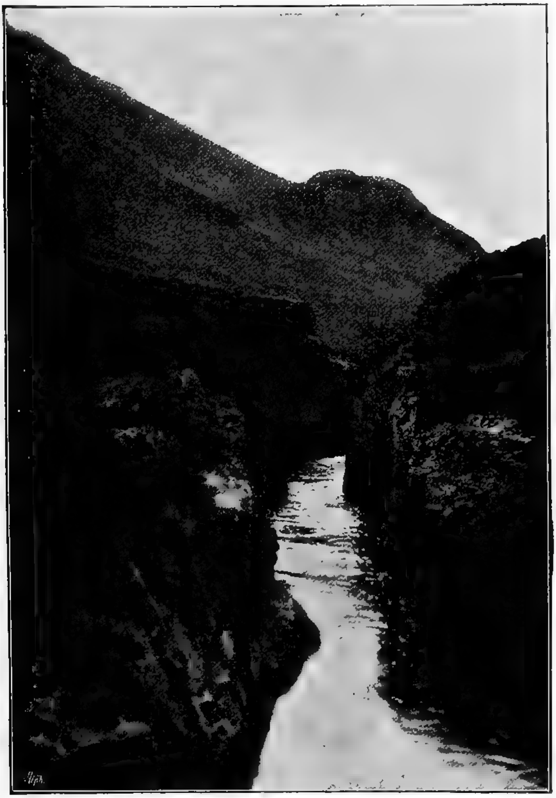


Fig. 142.—Gorge in Langstrath.

Scale Foss (Fig. 176, p. 394), near Crummock, owes its existence to the juxtaposition of soft Skiddaw slate and hard granophyre.[1] High Foss in Teesdale, Thornton Foss near Ingleton, the Aysgarth Falls in Wensleydale (Fig. 143), and many other

[1] J. E. Marr, *Proc. Geol. Ass.* vol. xvi. 1900.

Fig. 143.—Lower Fall, Aysgarth, Wensleydale, Yorkshire.

waterfalls or "forces," or more correctly Fosses, in the Lake District and Yorkshire, are due to the alternations of beds of hard limestone or igneous rock with softer beds of shale and sandstone.

Another cause of waterfalls and rapids is the fact that lateral valleys often come into the main valley at a much higher level.

The Yorkshire dales as they pass from the higher

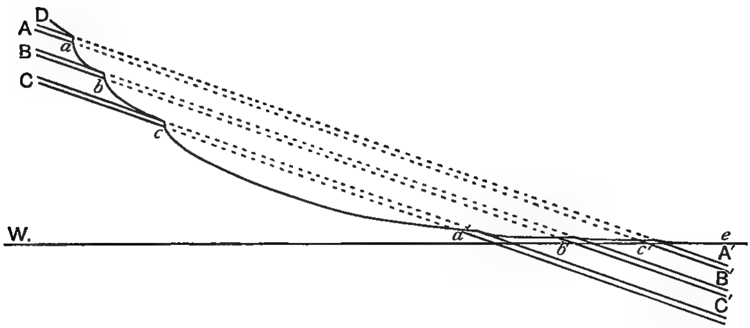


Fig. 144.—Diagram to illustrate the structure of certain Yorkshire River-valleys. *We*, sea-level; *De*, slope of valley; ABC, hard strata—the dotted lines show the parts removed by denudation; *abc*, waterfalls; *a′b′c′*, rapids.

ground with a steep slope expose along their sides lower and lower strata; but, as in the lower part of its valley, the stream passes successively over strata higher and still higher in the geological series (Fig. 144). In the language of William Smith, the streams in the Yorkshire dales first overcut and afterwards undercut the strata. Hence it happens that, as Phillips pointed out, "on the Tees, Swale, Yore (Ure), and Wharfe especially, the lowest beds of the Limestone series are exposed about the middle of the length of the dale, and in each valley water-

falls occur in the upper part, and rapids in the lower part, on the same Limestone beds."[1]

ON DRY VALLEYS AND UNDERGROUND RIVERS

The river system of a district depends much on whether the strata are pervious or impervious to water. In clayey regions, for instance, the rainfall runs off in rivers; where the strata are porous the rain does not run off, but soaks in and downwards, saturating the rock until it comes to some hard layer, clay or other impervious stratum, when it emerges in the form of a spring.

After heavy rains the porous stratum may become so saturated that the spring gushes out much higher up the valley than usual, and hence in such districts we find many valleys (Fig. 145), which are generally dry, but become water-courses after heavy rains.

A glance at the river-map (opposite p. 356) will show how comparatively waterless calcareous regions are. Contrast, for instance, the Chilterns or the Downs with Wales or Cornwall. In the former the rain sinks into the ground and there are few streams; in the latter the strata are much harder and more impervious, and the rain runs off in innumerable streams. The difference is not, however, completely brought out, because the smaller streams are only shown in maps on a very large scale.

In Chalk districts the surface often presents more

[1] *Geol. of Yorkshire*, Part II.

Fig. 145.—Dry Valley in Carboniferous Limestone, near Malham, Yorkshire, looking up from Coombe Scar.

or less circular depressions known as swallow-holes. Limestone rocks are often much fissured, and streams thus find their way underground and flow for some distance below the surface.

An interesting case is described by Miss Dale.[1] The Buxton Wye rises at the foot of Axe Edge,

Fig. 146.—Plunge Hole, on the Wye near Buxton. The Wye disappearing underground.

crosses the old High Peak railway, and disappears at a spot known as Plunge Hole (Fig. 146), between the railway and the great quarries of Grin Low. Under this hill is the well-known Poole's Cave (Fig. 147), through which the Wye runs, rising so high after heavy rains as to overflow and run out at the mouth of the cave. Under ordinary circumstances it disappears into another underground passage, and eventually

[1] Dale, *Scenery and Geology of the Peak of Derbyshire*.

reappears near some cottages on the Buxton road at a spot known as Wye Head.

Gaping Ghyll, a terrific chasm in the Limestone plateau of Ingleborough, more than 350 feet in depth, swallows up a stream, which emerges lower down in Clapdale.

The Ingleborough cave has been explored for over 700 yards, where the explorers found a large chamber from which water fell into a lake at a lower level.

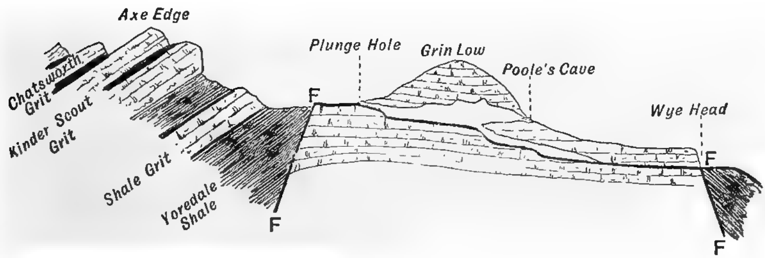


Fig. 147.—Section from Axe Edge to Wye Head to illustrate the formation of Poole's Cave and the underground course of the Wye. The thick black line in the Limestone indicates the river; FF, faults.

Hellan Pot, in the Craven District, lies on the east side of Simon Fell, about half a mile west from Selside. A dry valley, the former water-course, leads up to it. The shaft is 216 feet deep, and of considerable width.[1] The water emerges at Clapham Beck Head.[2] It is perhaps the most striking of the great swallow-holes in the Yorkshire Limestone district, and is nearly the deepest, being 359 feet in depth, Rowton Pot being 365 feet.[3]

The River Aire is generally stated to rise in Malham

[1] Tiddeman, *Mem. Geol. Surv.*, Ingleborough.

[2] *Brit. Ass. Report*, 1900.

[3] Cuttriss, *Brit. Ass. Report*, 1900.

Tarn, which is fed from a large area of Limestone rock. The overflow soon sinks into a cleft in the Limestone, and emerges a short distance below Malham village. It used to be supposed to form the stream which gushes out at the base of the precipice in

Fig. 148.—Spring at Malham Cove, one of the sources of the Aire.

Malham Cove (Fig. 148). It has, however, recently been ascertained that this stream is that which sinks into the ground at Smelt Mill.[1] It crosses the former underground but at a higher level. Springs rising at the foot of such escarpments are known as "Vauclusian," from the celebrated and typical instance at

[1] There have been some doubts as to the true source, but they seem to have been set at rest by inquiries conducted by two Committees of the Geol. and Polyt. Soc. of West Yorkshire. See "The Source of the River Aire," *Proc. Geol. and Pol. Soc. of West Yorkshire*, vol. vii. 1878-81, and xiv. 1900.

Vaucluse. At one time there evidently was a stream running above-ground and forming a waterfall in Malham Cove.

The Nidd also runs for some distance underground. In dry seasons the Mole disappears near Burford Bridge and runs underground for nearly 3 miles, reappearing near Leatherhead.

The Manifold passes through the Limestone hills about 3 miles south-west of Ecton in Staffordshire, and reappears 4 miles away at Ilam. During heavy rains, however, the subterranean passage[1] is not capacious enough to carry off all the water, and there is a stream above-ground also.

So frequent indeed are streams which are, as a rule, in part or entirely subterranean, but in wet seasons when the level of saturation reaches a high level appear above-ground, that they have received special names; in Yorkshire they are known as Gipseys, in the South as Bournes—such are, for instance, the Croydon Bourne, the Wiltshire Bourne, the Lambourne, and the Winterbourne.

On the other hand, it must not be supposed that there are as a rule subterranean rivers under the dry Chalk valleys. The whole Chalk is saturated, like a sponge; and where the plane of saturation intersects a valley, there a stream bursts out.

Fig. 149 represents a stream sinking into the earth.

An interesting case is afforded by the head-waters of the Thames flowing from the Seven Wells. Mr.

[1] Our English caverns have been well described by Professor Boyd Dawkins in his work on *Cave Hunting*.

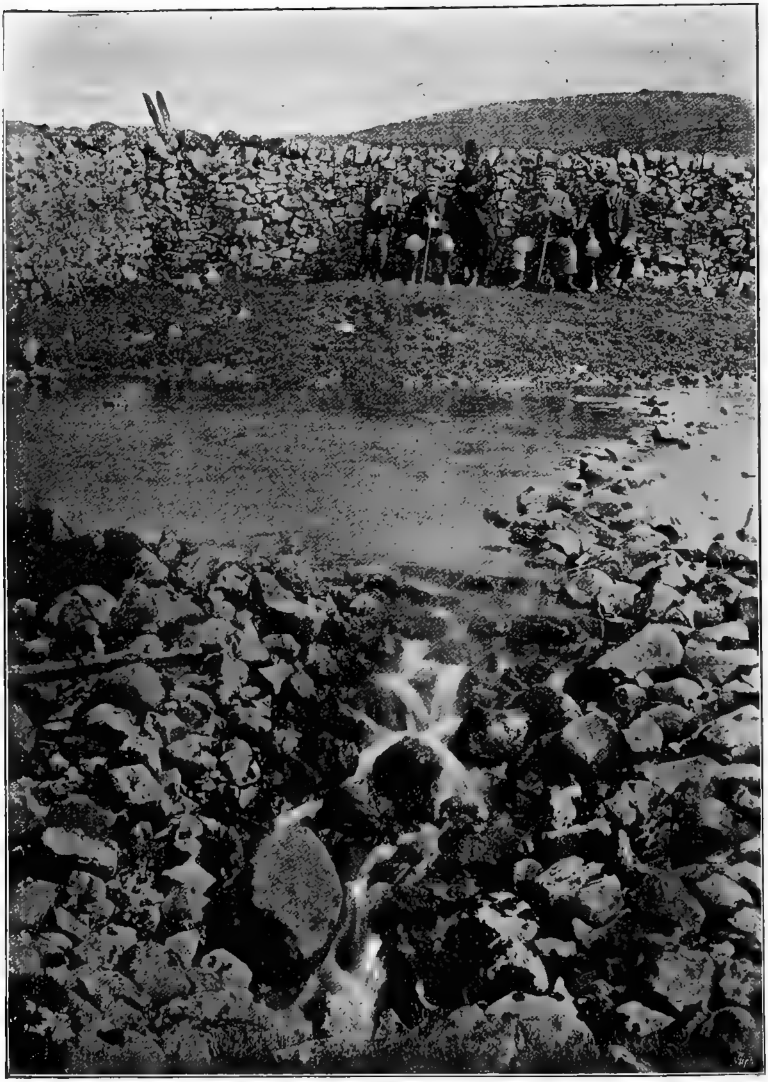


Fig. 149.—Stream from Malham Tarn sinking into the earth.

Simpson has measured[1] the flow for the first 15 miles, with the following curious result. The discharge from the spring-head was in one minute 11 cubic feet. For the first 5½ miles, which are over Lias clay, the flow gradually increased to 320 cubic feet. Then the river reaches the Oolites, into which the water begins to sink, so that the flow at—

6½ miles became	. . 290 cubic feet	
7	,, . . 235	,,
7⅜	,, . . 179	,,
8⅛	,, . . 113	,,
8⅞	,, . 45	,,
9¾	,, . . 33	,,
12½	,, . . 30	,,
14½	,, . . 10	,,

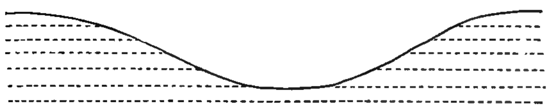


Fig. 150.—Diagram of a Valley of Erosion.

But though the Chalk areas are remarkably deficient in streams, they present a regular system of dry valleys. It has been objected that to suppose the former presence of streams in all the dry valleys of, say, the Mountain Limestone hills of Somersetshire, or the Chalk downs, would imply an extent of watershed which could never possibly have existed in the district. It is evident that these hollows are due to aqueous erosion, because they cut across the strata (Fig. 150). If they were due to subsidences the lines of stratification would, on the contrary (Fig. 151),

[1] Quoted by Phillips, *Geol. of Oxford, etc.*

follow the slope of the valley-sides. In many cases also the bottoms contain thick beds of gravel. It has been suggested that these valleys indicate a much damper climate than the present. No such supposition

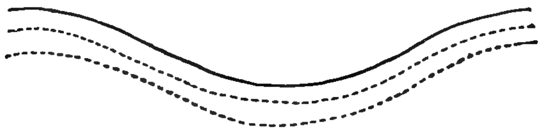


Fig. 151.—Diagram of a Synclinal Valley.

is, however, required to account for the facts. In ancient times, before the rivers had excavated their valleys to the present depth, and before the present drainage system had been so much developed, floods must have been more frequent. Moreover, during the glacial period, when the surface was frozen, the rain which now sinks into the pores of the Chalk must have run off in streams.[1]

As a general rule the subterranean drainage follows the direction of the rivers. But there are many exceptions. Suppose, for instance, that Fig. 152

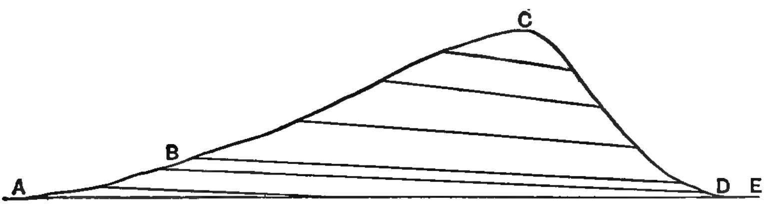


Fig. 152.—Diagram to show possible difference between Surface and Underground Drainage.

represents a section of any district, the watershed

[1] See Reid, "Origin of Dry Chalk Valleys," *Quar. Journ. Geol. Soc.* vol. xliii. 1887.

would be at C, and the streams on either side would run to A and E respectively. But if the strata have the inclination represented in the diagram, and if the one marked BD is impervious to water, the subterranean drainage of rain falling on the slope CB will not be towards A, but towards E.

Streams running over Limestone are also characterised by the absence of gravel, the products of erosion being all dissolved, except where, as in the case of the Chalk, it contains silicious nodules. On the other hand, in streams running over sandstones, shales, or volcanic rocks there is more or less sand, mud, or gravel.

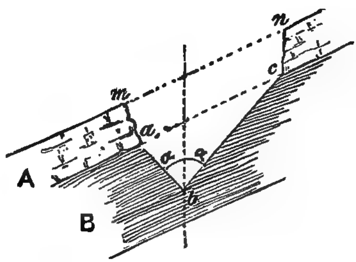


Fig. 153.—Diagram of a River-valley.

Hitherto we have assumed that the river deepens its bed vertically. This is not, however, always the case. If the strata are inclined the action of the water will tend to follow the softer stratum, as for instance in Fig. 153, which represents harder calcareous rock overlying a softer bed B.

The effect of this tendency of the courses of streams which run obliquely across inclined beds of different hardness, is that they tend to run across the hard and along the softer beds. Hard beds in fact throw off, and softer beds retain, streams.

Thus if a river were originally to run straight across a series of hard and soft strata, as in the

dotted line in Fig. 154, it would gradually be deflected to some such course as is shown by the hard zigzag line.

From the frequent presence of cross folds (see p. 184), and from the fact that the drainage of a district is in many cases modified by lines of fracture, it follows that tributaries have a tendency to enter streams at the same point; and, what is even more

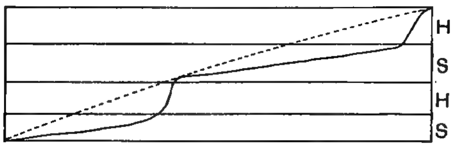


Fig. 154.—Plan of a Stream crossing inclined beds of hard (H) and soft (S) strata.

important, that streams often start opposite one another from the same watershed, giving rise to a depression. This has been suggested as the explanation of the well-known pass of Dunmail Raise in the Lake District, which connects the valley of Thirlmere with that of Grasmere. It has, however, been attributed by Marr to a line of weakness,[1] while it is regarded by Oldham[2] as the line of an ancient river before the elevation of the great Lake District boss.

CIRQUES

Many valleys terminate at the upper end in a "cirque" or amphitheatre-like cup. The cirques of Gavarnie in the Pyrenees, of Estaubè and Troumoure,

[1] J. E. Marr, *Scientific Study of Scenery*.

[2] *Quar. Jour. Geol. Soc.* vol. lvii. 1901.

are among the most magnificent examples. Many of the combes in our Limestone districts are also true cirques. I do not find in scientific literature any very clear explanation of their origin.

Let us, however, suppose a Limestone cliff or escarpment. The face will be gradually covered by "screes" until it assumes the angle of repose. Suppose, however, a spring bursts out anywhere along the face. The screes at such a point will sooner or later be removed, and a fresh face exposed to aerial action. Gradually therefore a niche will be formed, which by degrees will become deeper and deeper. The face of the rock at the sides immediately adjoining the spring will be nearly perpendicular, but the slope will become gentler as we descend the valley, because the atmospheric agents will have had a longer time in which to act.

MEETING OF STREAMS

Every one must have observed that while lateral streams generally join the main stream at a level, as for instance CB in Fig. 155, in mountainous countries, on the other hand, the lateral streams in many cases join the main valley at a higher level (Fig. 155, DB), falling in by rapids or waterfalls. Along the Valais and the Reuss, for instance, this is very striking; in the Lake District the waterfall of Lodore is a well-marked case.

It has been suggested that this is because, *cæteris paribus,* the erosive power of the water increases with

the quantity of water. Hence if the strata and the inclination are the same, a large river will erode more quickly than a small one. The lateral streams, there-

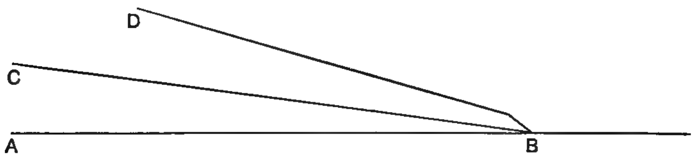


Fig. 155.—Diagram showing junction of a Stream and Tributary.

fore, are at first left, so to say, behind, and their valleys are at a higher level than that of the main river (Fig. 155, DB).

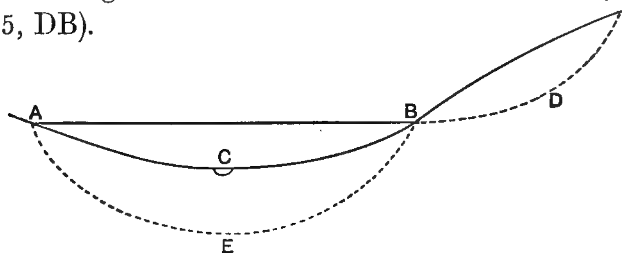


Fig. 156.—Diagram showing junction of a Stream and Tributary.

Another manner in which this fact may probably be accounted for, at any rate in some cases, is as

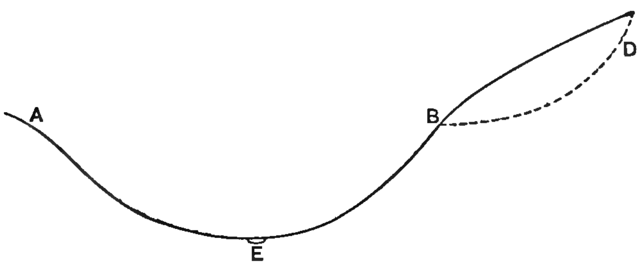


Fig. 157.—Diagram showing junction of a Stream and Tributary.

follows:—Let ACB (Fig. 156) be the valley of a stream C, and let the dotted line D represent the bed of a lateral affluent. Now suppose the valley ACB to

be filled by a glacier up to the horizontal line AB (Fig. 156). The glacier may continue to excavate its bed to the level shown by the dotted line AEB, but the upper level of the ice will dam back the lateral stream, and constitute, as regards the lateral valley, a base line at the level AB, below which the lateral stream cannot excavate its valley. Hence when the glacier finally disappears we shall have such a section as that in Fig. 157, where the lateral stream has in its upper part a gentle slope, but joins the main stream with a rapid descent.

THE POSITION OF WATERSHEDS

As the work which a river can perform will, other things being equal, depend upon the fall, a river with

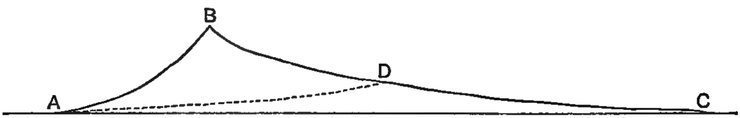


Fig. 158.—Diagram to illustrate position of Watershed.

a slope such as AB in Fig. 158 will be more powerful than one with a fall of BC. Hence if two rivers start at B and fall into the sea at A and C respectively, the river BA will lower its bed more rapidly than BC, and will gradually cut back its valley, encroaching on the territory and annexing the tributaries of BC until it reaches the point D, when equilibrium will be attained. The steep northern and gentler southern slope of the Alps is a case in point, and the watershed is gradually moving northwards. In our own

country the eastern tributaries of the Severn are in the same way encroaching on the territory of the Thames.

It is a very general rule where rivers run down an inclined plane from the edge of an escarpment, that the lowest places on the summit ridge correspond generally to the termination of the longest dales. Phillips long ago noticed this in the case of the Pennines, and particularly mentions "the head of Maize Beck and the Tees in Teesdale, Stainmoor along the course of the Greta, Helgill at the head of Yoredale, and a pass at the head of Swaledale above Kirkby Stephen."[1]

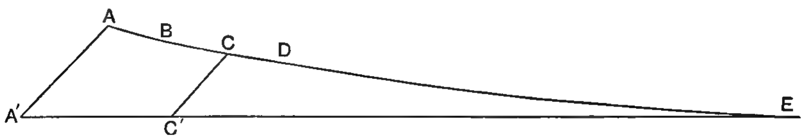


Fig. 159.—Diagram to illustrate Depressions on Summit Ridges.

In the case of escarpments such as the Downs, we must remember that the present is by no means the original position of the ridge. Suppose, for instance, that AA′ (Fig. 159) is any escarpment, and that rivers run down the slope ABCDE. They would rise not exactly at the edge, but wherever the water supply was sufficient, say at B. Now suppose the escarpment worn back from AA′ to CC′, the river would rise, say at D, but the old valley would remain as a dry valley and would form a depression in the ridge of the escarpment.

This seems likely to be of frequent occurrence in

[1] Phillips, *Yorkshire.*

the cases of escarpments. But there is another general cause which would tend to produce the same result, and to which in many cases the fact may be entirely due.

Let AA, Fig. 160, be two streams falling into the sea or a lake at BB, and let K′LM be the line of watershed. Assuming the rocks to be uniform, a slope will gradually be established round AA, and

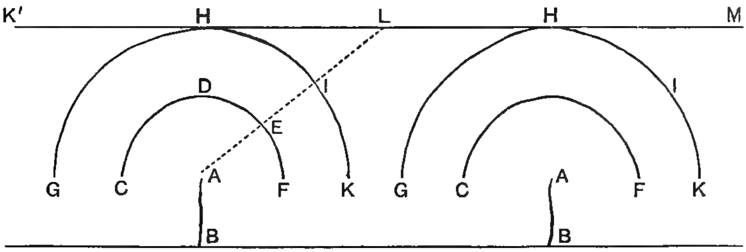


Fig. 160.—Diagram to illustrate Depressions on Watersheds.

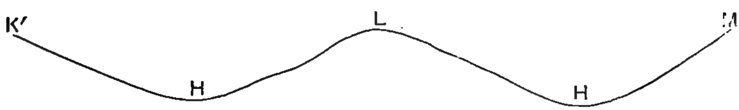


Fig. 161.—Levels along the line K′HLHM in the preceding figure.

all points at the head of the valley equidistant from A will be reduced to approximately the same level. Hence the contour lines will assume a course equidistant from A and A, and all the points on the line CDEF and GHIK respectively will have the same elevation. Hence the height at H and I is equal. But as H is on the watershed, the ground beyond H will slope down towards the next valley. On the other hand, as the slope extends beyond I to L, L must be higher than H. Hence the summit of

the watershed will assume the curve K′HLHM in the section, Fig. 161, the lowest points HH being those opposite the river-valleys AA, and the highest points K′LM being farthest from them. This is one reason, I believe, why the lowest points on a ridge are so often at the ends of the longest valleys, running up towards it. If, on the contrary, the streams on each side of a watershed alternate, it will assume a zigzag course; and as the distances ac, a^1c, a^1e, a^2e in the plan (Fig. 162) are shorter than ab, ad, a^1d, a^1f, etc., the points bdf will be higher than c and e. See, for instance, Fig. 98, p. 263, showing the district of the Brecknock Beacon.

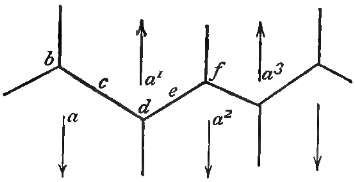


Fig. 162.—Plan of a zigzag Watershed.

Valleys and rivers are so closely associated with one another, that we generally think of them as inseparably connected; and indeed there are but few valleys which have not been deepened and profoundly modified by the action of water.

Nevertheless, many valleys are "tectonic," that is to say, they are due, or stand in a definite relation, to geological structure; indeed, when we consider how generally elevation is due to compression, and mountain ranges to folding, we might naturally be disposed to regard valleys as being generally the result of synclinal folds. There are no doubt such cases, and the district of the Jura is a well-known case (Fig. 59, p. 188).

The valley of the Rhine below Basle is also a line of subsidence, and the two crystalline regions of the Black Forest and the Vosges were once continuous. The Kennet-Thames and some other English valleys belong to this class.

Valleys belong to several different classes, and in Switzerland have received special names, such as Vals, Combes, Cluses (*clausa*, closed), Ruz, Cirques, etc., names, however, which do not cover all the different kinds, and are not always used in the same sense.

In many cases valleys follow the "strike" or outcrop of the strata, in which case they are termed, as first suggested by De Saussure, longitudinal valleys; while in others they cut across the strata, and are known as transverse or cross valleys, or cluses.

TRANSVERSE VALLEYS

Transverse valleys cross the strata more or less at right angles. They are generally narrow, and often form deep gorges, more or less encumbered by fallen rock, and the harder the rock the narrower the valley. Their character is greatly influenced by the nature of the strata, their inclination, and whether the fall coincides with, or is in opposition to, the dip of the beds.

Unless the fall of the ground coincides exactly with that of the strata, a river running along a transverse valley will generally cross here and there harder layers which give rise to cataracts or waterfalls.

When the strata are horizontal the action of running water is comparatively slow. Steeply inclined or vertical strata, on the other hand, greatly facilitate erosion. Not only does the force of gravity take part in the labour, but the water sinks in more easily, and both chemical and mechanical disintegration is thus much increased.

LONGITUDINAL VALLEYS

Longitudinal valleys are of several kinds. Some are *synclinal* (Figs. 57-59, p. 187), and occupy the depressions of folded strata. For the reasons, however, already given (ante, p. 189), these are comparatively rare.

Others are *anticlinal* (Fig. 57, p. 187), when the arch between two synclines is broken, and the action of water being thus facilitated, a valley is formed, of which in our country the Tay affords a striking example.

In both these cases the strata are the same on the two sides of the valley. A third class of longitudinal valleys is due to the outcrop of a softer stratum between two harder ones (Fig. 166, p. 365).

In other cases rivers run along faults. The valley of the Usk, says Symonds, "runs along a fault which has upheaved the Old Red hills of the Black Mountains, on the north bank of the river, and depressed the strata on the south." [1]

Nevertheless, so effective was the planing which

[1] *Records of the Rocks.*

took place as the land rose gradually out of the sea, and so great has been the amount of denudation, that such "tectonic" valleys are comparatively rare, and the great majority are due to the action of rain and rivers.

Thus, though the general direction of rivers is determined primarily by geological causes, the valleys have been mainly excavated by the rivers themselves.

When, indeed, we consider a great valley and look at the river flowing through, it may seem impossible that the stream should have had so great an effect. Any one, however, who has seen the quantity of stones and boulders brought down by mountain torrents after heavy rains, or has noticed how turbid rivers are during floods, will admit how great the effect must be, especially when we bear in mind the length of time.

CHAPTER XI

THE COURSES OF ENGLISH RIVERS

We will now proceed to apply the general considerations which have been discussed in the preceding chapters to some of our principal English rivers.

The general direction of the river-courses in any country is determined in the first instance by the configuration of the surface at the time of its becoming dry land.

The least inequality in the surface would determine the first directions of the streams, which would carry down any loose material, and thus form little channels, which would gradually be deepened and enlarged. The course first adopted would in most cases be maintained—it is as difficult for a river as for a man to get out of a groove; and yet, as we shall see, there have been some great changes.

If we imagine a district raised in the form of a regular dome, the rivers would tend to radiate with more or less regularity from the centre or axis of the dome, as for instance in our English Lake District. Derwentwater, Thirlmere, Coniston Water, and Windermere run approximately N. and S.;

Crummock Water, Loweswater, and Buttermere, N.W. by S.E.; Wast Water, Ullswater and Hawes

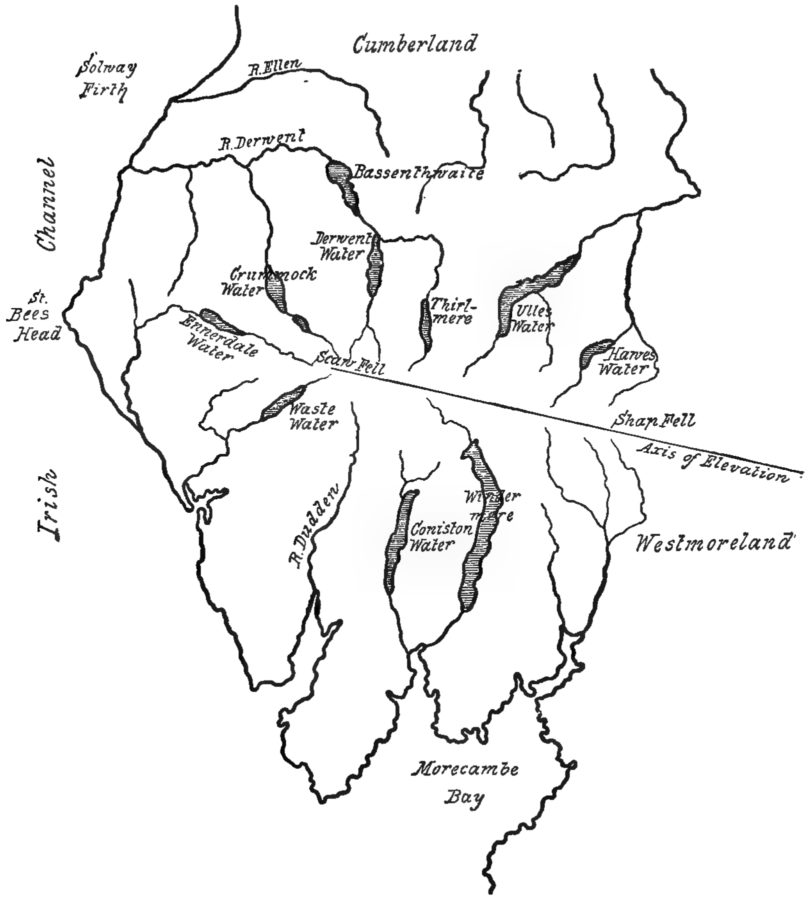


Fig. 163.—Sketch-map of the Lake District.

Water, N.E. by S.W.; while Ennerdale Water lies nearly E. by W. Can we account in any way, and if so how, for these varied directions?

The mountains of Cumberland and Westmoreland form a more or less oval boss, the axis of which,

though not straight, runs practically from E.S.E. to W.N.W., say from Scawfell to Shap Fell; and a sketch-map (Fig. 163) shows us almost at a glance that Derwentwater, Thirlmere, Ullswater, Coniston Water, and Windermere run at right angles to this axis; Ennerdale Water is just where the boss ends and the mountains disappear, while Crummock Water and Wast Water lie at the intermediate angles.[1]

It is probable that since the Lake Country rivers began to run in approximately their present courses, the general level of the country has been lowered by denudation to an extent of at least 2000 feet.[2] It follows that while the great boss or dome of the Lake District is older than, and has determined the courses of, the rivers,—the rivers, on the other hand, are older than the separate mountain-tops, which are indeed residuary masses, carved out by the action of the rivers.

On the plateau of Lannemazan in the South of France the rivers also radiate from a centre, which, however, in this case is an immense river-cone (see p. 310) of stones and mud—covering 1300 kilometres,—of fluvio-glacial origin, and with a very gentle inclination.

It seldom happens, however, that the case is so simple as in these instances, and the directions of rivers offer many interesting problems.

An interesting fact in connection with our rivers,

[1] Hopkins, "On the Elevation and Denudation of the Lakes of Cumberland and Westmoreland," *Quar. Jour. Geol. Soc.* vol. iv. 1848.

[2] Goodchild, "Hist. of the River Eden," *Trans. Cumb. and West. Ass.* 1888-89.

to which I have already alluded, is that, as any one who will look at a map which shows the course of our rivers plainly (and this is unfortunately an exception) can hardly fail to notice,[1] that in several districts they rise close to the sea, and then run directly away from it, in some cases, however, turning round and debouching into it at no great distance but after a considerable detour. The Alan or Camel rises not far from the sea in Bude Bay, runs south-west, and then curving round falls into the sea near Pentire Point. The Tamar and the Exe rise near the Bristol Channel and run south to the English Channel. The Torridge rises near the west of Bideford Bay, flows south, and then round by the east to the east end of the same bay. On the Norfolk coast the Ouse, the Yar, and the Bure rise close to the sea and flow away from it. One branch of the Derwent rises close to Filey Bay, much nearer in fact than most maps indicate, and running inland falls into the Ouse, and so into the Humber. In the Isle of Wight the Medina and the two Yars rise quite in the south of the island, almost below high-water level, and running through the backbone of the island fall into the Solent. Some of the Welsh rivers behave in a similar manner. The West Cleddau, for instance, rises near Strumble Head in Cardigan Bay, and running straight inland falls into Milford Haven.

In such cases, if the coast had long been in its

[1] The map here given (p. 356) is taken from an excellent river-map of Great Britain published by Stanford.

present position, direct channels to it must have established themselves. The course of the rivers indicates that when they commenced to flow in their present lines the sea must have been at a much greater distance.

It may indeed be said that there is high land close to the coast, and that the surface slopes away from it; but this again is itself additional evidence that the present coast-line is of comparatively recent origin.

In many cases river-courses have been determined by lines of weakness due to faults.

For instance, the Linn, the Rawthey, and the (W. Yorkshire) Dee,[1] with some of their tributaries, coincide with lines of fault; the Rhaiadr[2] also runs upon a line of fault, the beds on the west being raised.

The Vale of Clwyd is mainly due to a great fault, running a little west of north, which has thrown down the Carboniferous rocks westwards far below the general level of the platform of Silurian strata on which they rest, and the trough thus produced has subsequently received great deposits of red sand of Triassic age.[3]

This valley is remarkable as the only one in "England or Wales where the Mesozoic rocks lie so enclosed as if in a long bay in the heart of the Palæozoic formations, and it is this that gives a charm so peculiar to the scenery of this remarkable valley."[4]

[1] Davis and Lees, *West Yorkshire.*
[2] Symonds, *Records of the Rocks.*
[3] Strahan, *Mem. Geol. Surv.*, Flintshire.
[4] Ramsay, *Mem. Geol. Surv.*, North Wales.

If we look at any sufficiently large map it will be seen, especially in the North of England, that while rivers generally pursue more or less meandering courses, here and there a stream, or part of a stream, runs in a straight line. This generally indicates the existence of a fault, constituting a line of weakness,

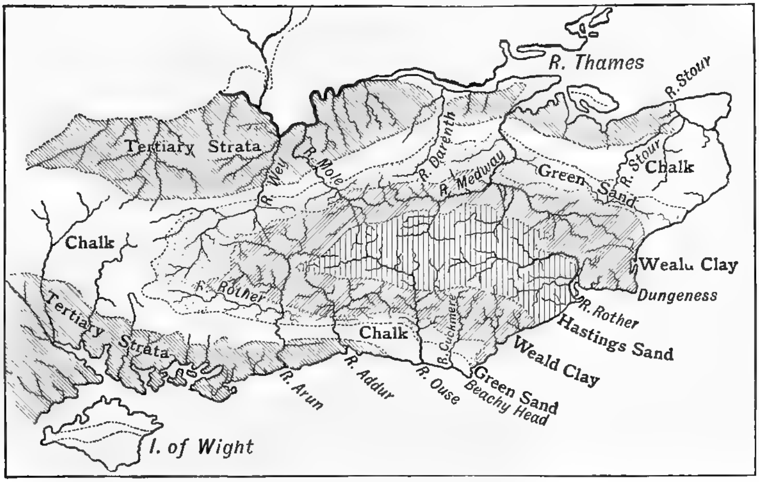


Fig. 164.—Sketch-map of the Weald.

which has determined the course of the stream, and checked its natural tendency to wander.

We might perhaps have expected that rivers would frequently occupy synclinal valleys. On the contrary, they have what at first sight appears an unaccountable tendency to cut through escarpments.

The distribution of the rivers of the Weald (Fig. 164) is a remarkable case. The high Chalk ridge which runs round the Weald is cut through by several rivers, some on the north, some on the south.

The explanation was first, I believe, suggested by

C. Le Neve Foster and W. Topley,[1] and applies to many other cases where rivers cut through escarpments.

The axis of the Weald runs from Winchester by Petersfield, Horsham, and Winchelsea to Boulogne; and, as shown in the section (Fig. 106, p. 278), we have on each side of the axis two ridges or "escarpments," one that of the Chalk, the other that of the Greensand, while between the Chalk and the Greensand is a valley, and between the Greensand and the ridge of Hastings Sand an undulating plain, the strata north of the line of elevation dipping to the north, those on the south to the south. Under these circumstances we might have expected that the streams draining the Weald would have run in the direction of the axis of elevation, and at the bases of the escarpments (as, in fact, the eastern Rother does for part of its course to the sea between the North and South Downs), instead of which as a rule they run north and south, cutting in some cases directly through the escarpments: on the north, for instance, the Wey, the Mole, the Darent, the Medway, and the Stour; and on the south the Arun, the Adur, the Ouse, and the Cuckmere.

They do not run in faults or cracks, and it is clear that they could not have excavated their present valleys under circumstances such as now exist. They carry us back, indeed, to a time when the Greensand and Chalk were continued across, or almost across,

[1] "On the Superficial Deposits of the Valley of the Medway, with remarks on the Denudation of the Weald," *Quar. Journ. Geol. Soc.* vol. xxi. 1865.

the Weald in a great dome, as shown by the dotted lines in Fig. 106, p. 278.

They then ran down the slope of the dome; and as the Chalk and Greensand gradually weathered back—a process still in operation,—the rivers deepened and deepened their valleys, and thus were enabled to keep their original course.

Other evidence in support of this view is afforded by the presence of gravel-beds in some places at the very top of the Chalk escarpment—beds which were doubtless deposited when what is now the summit of a hill was part of a continuous slope.

The axis of the Weald shows also a series of gentle undulations, and the rivers naturally ran in these hollows down the main slope.

Suppose, for instance, three rivers (Fig. 165, *aa*, *bb*, and *cc*) running down to the sea over an inclined plain on which strata of different hardness crop out, *dd* being hard and *eee* comparatively soft. Speaking generally, we may say that the depth of a valley is due to erosion, the width to weathering. Hence the river-valleys will be narrower where they cross the strata *dd*, and broader where they cross *eee*.

The dotted portion represents the valley, with the stream in the centre. Moreover, aerial action will affect the soft strata *eee* more than *dd*. They will, therefore, be lowered, and streams will tend to run along them and fall into the primary rivers.

Rivers which run down the slope or "dip" of an arch may be conveniently termed "dip" rivers; and those which run along the strike of strata, as for

instance the lateral streams in Figs. 165 and 166, may be called "strike" rivers.[1]

Should it, however, happen—and such could hardly fail to be often the case—that the primary streams were of unequal magnitude, the more powerful would lower their beds more quickly; their affluents thus obtaining a greater fall, would also eat their way back more rapidly.

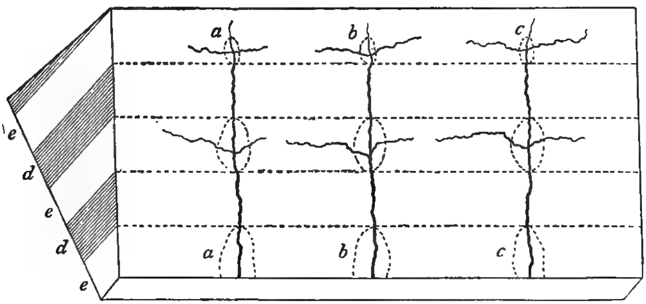


Fig. 165.—Diagram of initial River Courses.

Suppose, for instance, that *bb* had an original advantage over *cc*, and still more over *aa*. Its affluents would eat their way back, and at length tap *aa* and *cc*, carrying them off to *b*. The lower part of the valleys *aa* and *cc* would then only contain comparatively small brooks out of all proportion to the valleys, *aa* being shortened even more than *cc*.

The whole circumstances and conditions of river action are so variable and complex, that *b* might conceivably annex part of the head-waters of *c* and almost the whole of *a*, as shown in Fig. 166.

We have such a case in the Weald (Fig. 164, p.

[1] Professor Davis has suggested a somewhat more complex nomenclature.

361). The Chalk may be taken to represent the hard stratum *d*; the little stream to the west of the Arun, which is known as the Lavant,[1] our stream *a*; the Arun *b*; and the Adur *c*. It will be seen that the tributary of the Arun, known as the Rother, running along the Lower Greensand valley, passes behind the Lavant, and has appropriated its head-waters; while what is regarded as the main river, though it is really

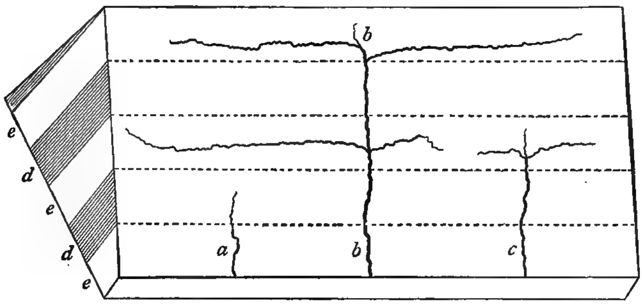


Fig. 166.—Diagram of the same River Courses more advanced.

a lateral affluent, rises in the east, south of Horsham, and quite behind the present head-waters of the Adur, which has been robbed by the Arun on one side and the Ouse on the other. The Lavant, which like the Adur may be called a beheaded river, has been reduced to quite a small stream, in dry weather even to a succession of pools. The Chichester estuary also, which was evidently once the mouth of a large river, is now a comparatively wide valley without any river at all.

Farther to the north the relations of the Thames with the Severn, the Trent, and the Ouse offer problems of great interest and difficulty.

[1] The term Lavant is applied in Sussex to any occasional streams.

As regards the relations between the Thames and the Severn two theories have been held.

Sir A. Ramsay regarded the lower Severn valley as being "one of the oldest in the lowlands of England."[1] He thought that the secondary strata to the south-east sloped towards and drained into the Severn. Their present tilt to the south-east was, he considered, the result of later earth movements. If, as he supposes, the earlier slope of the Secondary strata was towards the west, "why," he asks, "is it that the Thames and some other rivers that flow through the Oolites and Chalk run eastward?" The answer, in his opinion, was that after the original valley of the Severn was well established by its river, a new disturbance of the whole country took place, by which the Cretaceous and other strata were slightly tilted eastward, not suddenly but by degrees, and thus a second slope was given to the Chalk and Eocene strata, in a direction opposite to the dip that originally led to the scooping out of the present valley of the Severn.

"When this slope of the Chalk and the overlying Eocene strata was established, the water that fell on the long inclined plain, east of the escarpment of the Chalk, necessarily flowed eastward, and the Thames, in its beginning, flowed from end to end entirely over Chalk and Eocene strata."

According, then, to this view the Severn would be an older river than the Thames.

When the reversal of the slope took place, the

[1] *Physical Geol. and Geog. of Gt. Britain.*

valley of the Severn was already formed. From the summit of the eastern side of the valley the Thames and other rivers then began running to the south-east. I am not, however, aware that there is any geological evidence of this change in the dip of the beds.

Ramsay has, moreover, himself shown (see Fig. 20, p. 94) that from the Welsh watershed there was a gradual eastward slope far away across the country to the east coast.

Again, under his theory it seems difficult to understand the origin of the Goring Gap, or of the other depressions which notch the escarpment at intervals along its whole course, just as is the case with the Chalk escarpment of the Weald, and, I believe, from the same cause.

I now, therefore, come to the second view, which was, I believe, originally suggested by Dr. Ellis[1] of Gloucester, and has been supported by Professor Davis[2] and Dr. Buckman.[3] We know that flint gravel, indicating the presence of Chalk, occurs as far west as Devonshire; the Chalk is well developed in the North of Ireland; and evidence of its presence occurs in Scotland. Now, the Chalk was an oceanic deposit, formed in moderately deep water and, as shown by the absence of pebbles, probably at least 200 miles from land, which would carry it across Wales to the Irish Sea, where it probably joined the Chalk of Antrim and South Scotland, even if some of the Welsh and Scotch mountains rose as islands

1 "On the Formation of the Severn Valley," *Phil. Soc. of Gloucester*, 1882.
2 "On the Development of certain English Rivers," *Geog. Journ.* vol. v. 1895.
3 "On the Development of Rivers," *Nat. Science*, vol. xiv. 1899.

above the waters. That the Lias also once extended far to the west is shown by the outlying patches still remaining at Carlisle, near Wem, and Cardiff.

If we look at the fretted and gullied escarpment of the Oolitic range from Northampton to Somerset; follow the level sheets of Lias and Trias down the coasts of Somerset and Glamorgan till they abut against the Palæozoic hills on both sides of the Bristol Channel; connect in imagination the promontories of the ridge with the outliers in the plain, such as Bredon Hill; then mark how the Oolitic outliers get fewer and smaller as we recede from the escarpment; note the curious little patch of Inferior Oolite that caps the Lias peak of Brent Knoll, which rises from the flats of Bridgewater, and the still farther outlying patches of Lias that here and there cap the red marls of Staffordshire, Warwickshire, and Cheshire,—it is evident that the Jurassic and Cretaceous rocks must have formerly extended far to the west.

This suggests some very interesting considerations as regards the Severn valley and its relations to the Thames. The map (p. 356), shows that the upper continuation of the lower Severn is really the Warwick Avon, and that the upper Severn, though larger than, is a tributary of, the Avon. The line of the Warwick Avon, just before its Evesham bend, is continued up the valley of the Isborne, the head of which is only separated by a road from the upper waters of the Coln. The valley, moreover, is continuous, and 250 feet deep at the watershed.

The curve made by the Warwick Avon, near

Evesham, is perhaps caused by the presence of Bredon Hill (p. 275), itself probably due to a fault.

It is probable that the whole drainage west of the watershed of England originally ran over Secondary strata; and that the older rocks, over which the upper Severn and its tributaries now flow, were only exposed by subaerial agencies acting over a long period of time.

It is clear, moreover, that in the south also the Lias, Oolite, and Chalk once extended far beyond their present limits, covered the Carboniferous Limestone of Clifton Downs, and extended into Somersetshire and Wales, resting on the Palæozoic strata of the west.

The relations of the Thames and the Severn are very interesting from several points of view.

Buckland, as long ago as 1821,[1] observed that the gravel of some of the Thames tributaries contained pebbles which must have come from the north-west. He traced them over the valley of the Severn and across the Cotteswolds, through the gap between Shipton and Moreton-in-the-Marsh, down the Evenlode to the Thames; and again in another gap through the Oolite escarpment by Fenny Compton, down the valley of the Cherwell. He was confirmed in his facts by Hull[2] and Lucy.[3] Buckland, in accordance with the ideas of the time, associated this transport with the deluge; Hull regarded these gravels as a marine deposit belonging to the glacial period, and attributed the valley through the Cotteswolds to

[1] *Trans. Geol. Soc.* vol. vi. 1821.
[2] *Quar. Jour. Geol. Soc.* vol. xi. 1855.
[3] *Proc. Cotteswold Nat. Field Club*, vol. v. 1872.

marine agency. Lucy was also disposed to adopt the same view. Phillips, in his work, *The Geology of Oxford and the Valley of the Thames,* showed that the facts could not be accounted for by marine action, but did not attempt any actual explanation.

In the Moreton valley, at the head-waters of the Evenlode, on the present watershed, there is a mass of river gravel containing Triassic pebbles, and showing that the Evenlode was once a large river draining the Triassic area to the north-west.

In fact, Shrubsole describes[1] the gravel at Upper Basildon, at a level of about 455 feet, as containing only 15 per cent of flint, and consisting mainly of purple and brown quartzite pebbles from the Bunter beds of the Midland Counties; but he adds that "as the later stages of this gravel clearly indicate ice-action, we have in that alone an agent sufficient to account for the changes that have taken place."

Another consideration is that the upper Thames valleys are out of all proportion to the diminutive streams running through them. The contrast between the Cherwell and its valley is very marked, especially between North Aston and Somerton, near Upper Heyford and at Enslow.[2] The head-waters of the Evenlode are in a wide valley. Between Stonesfield and Long Hamborough there are, as Buckman has pointed out,[3] three valleys one within the other. One with the wide sweeping curves of a large river,

[1] *Quar. Jour. Geol. Soc.* vol. liv. 1898.

[2] Davis, "The Drainage of Cuestas," *Proc. Geol. Ass.* vol. xvi. 1899.

[3] "On the Development of Rivers," *Nat. Sci.* vol. xiv. 1899.

a second with the meanders of a stream, the third the smaller windings of a mere brook. The main valley was excavated by a large river which drained the country west of Cheltenham and Gloucester. The second valley belongs to the period when the river had lost its western branch; and the third is that of the present little brook.

Moreover, the Goring gap, through which the Thames passes, is not the only one cut through the Chalk escarpment.

These dry gaps or depressions at the heads of the valleys are very impressive. That on the road from Wendover to Aylesbury, as Gregory has pointed out,[1] above the sources of the Miss, is 300 feet deep, the summit of the pass being 503 feet above the sea, while the ridge on either side rises to 790 and 800. The next gap to the west, on the road from West Wycombe to Princes Risborough, is 270 feet in depth, the pass being 427 feet and the hills on either side 700. Moreover, the floors of the valleys are occupied by unmistakable river gravels.

The dry Ogbourne valley, north-west of Marlborough, is probably the old bed of the Churn, which was originally a tributary of the Kennet, before it was captured by what is now called the Upper Thames. Along it runs the Roman road from Cirencester to Winchester. The Lambourne valley was the course of the Coln.

Again, as the map (p. 356) shows, while the tributaries on the Welsh side of the Severn join that river,

[1] "The Evolution of the Thames," *Natural Science*, vol. v. 1894.

as we should naturally expect, in a direction with the stream, several of those on the east side run in a direction against that of the main river, so that if we only saw their middle reaches we should certainly regard them as tributaries, not of the Severn but of the Thames; and they appear to occupy valleys originally formed by larger streams, not running to the Severn, but to the Thames.

From these considerations it seems probable that the western Welsh rivers, including the upper Dee, the upper Mersey, the upper Severn, and the Wye, were at one time tributaries of the Thames.

In this case we may assume that when England "arose from out the azure main," the general slope was towards the south-east, and the streams ran in that direction until, diverted by the rising ground due to the elevation of the Weald, they collected into one great river running nearly east and west along the foot of the dome of the Weald—the future Thames. Davis suggests that the upper Severn represents the head-waters of either the Cherwell or the Evenlode: I should have thought that the doubt would rather have been between the Evenlode and the Windrush.[1]

However this may be, the Cherwell, the Evenlode, and the river from Oxford to Reading are the longest remaining parts of the original river. The Cherwell and the Evenlode both drain a moderate area of Lias country beyond the Oolitic escarpment, and thus lie between the conflicting head-waters of the

[1] "Development of certain English Rivers," *Geogr. Jour.* vol. v. 1895.

Warwick Avon on the west, Bedford Ouse on the east, and Trent on the north.

As Western Wales was gradually denuded of its Secondary strata, the Chalk gradually formed an escarpment, which has retreated and is retreating south-eastwards; it now forms the Berkshire Downs and the Chilterns. Somewhat later the same happened to the Oölites, the escarpment of which is known as the Cotteswolds.

In the meanwhile minor streams ran into the sea, along the south and south-west of Wales, and of course the degree to which they were able to deepen their beds and to eat their way back inland, depended to a great extent on the weakness of the strata over which they flowed.

The denudation of the Chalk and Oolite having brought the Lias and New Red Sandstone to the surface, the stream draining the country now occupied by the lower part of the Bristol Channel ran over specially soft strata, and, having a steeper fall to the sea, was able to excavate its bed with exceptional rapidity. This gave rise to the lower Severn, while similar conditions in the north-east are perhaps the cause of the existence of the Wash.

The small river which then occupied the site of the present Bristol Channel first annexed the Usk, then successively the Wye and the upper Severn, and, being able to give them a more rapid fall to the sea, detached them from their allegiance to the Thames.

If this view is correct, the Thames is an older, and was formerly a much larger, river than the original Severn. The Severn began as a small brook, which gradually ate its way back, and, annexing the rivers of Western Wales, cut them off from the Thames and deprived it of most of its head-waters. This theory would account for the wind-gaps and dry valleys on the Downs and the Cotteswolds, for the magnitude of the valleys in comparison with the streams which now flow through them, for the presence of pebbles from the north-west in the Thames, and for the apparently reversed courses of many of the eastern affluents of the Avon and the Severn.

The Thames above Oxford is also a "strike" river (see p. 364) and comparatively recent, the Teme, the Wye, and the Usk having run into the Kennet, and so joined what we now call the Thames at Reading.

In any case, there can be no doubt that the retreat eastwards of the Oolitic and Chalk escarpments is gradually, though of course very slowly, reducing the water supply of the Thames, and that the Avon and the Ouse have cut off and annexed some of the upper tributaries. The Ray, Miss, Chess, Coln, Gad, Ver, Lea, and Beane are the lower parts of beheaded streams.

Nor is the Severn the only enemy of the Thames. The river-map (p. 356) shows that the Ouse is gradually stealing towards the Cherwell, and if allowed to work its way back for little more than a mile it will carry off the upper half of the Cherwell area, detach it from the Thames, and annex it to the

basin of the Ouse. Indeed, along the whole line of the Chilterns the Thames is receding, though of course very slowly, and the tributaries of the Great Ouse are gaining ground.

The present source of the Thames is about 600 feet above the sea; in 9 miles it has descended the first 300, and in 11 more another 100, to the 200 contour line near Lechlade, after which it takes 72 miles to fall to 100 feet, which is reached near Great Marlow, and 48 miles more to the 25-foot level at London Bridge.[1]

When the river cuts through the Chalk escarpment at the Goring gap, the top of the Chalk near the river, though considerably higher than the water, is about 100 feet lower than the river source.

What we now call the Thames is, in reality, by no means a single homogeneous river. The direct valley of the lower Thames runs up the Kennet. The Oxford river is a northern affluent. But the direct valley of this affluent above Oxford is the Cherwell, and the so-called Thames above Oxford is a "strike" stream (see ante, p. 364), which has cut its way back and annexed the Evenlode, the Windrush, the Leach, the Coln, the Churn, etc., rivers which previously ran south-east into the Kennet. Streams which were originally tributary often become in course of time so considerable that they are regarded as the main river; and in many cases where we speak of a river suddenly changing its direction, it would be perhaps more correct to say that it falls

[1] De Rance, *Proc. Geol. Ass.* vol. iv. 1875.

into the valley of another river. Thus we give the name of the "Thames" to the whole stream which runs from the Cotteswolds to London. The head-waters, however, at Oxford adopt the valley, or at any rate the line, of the Cherwell; and at Reading of the Kennet, which is really the continuation of the lower Thames valley.

The upper waters of the Thames are still, though slowly, deepening their valleys. The central part is almost stationary. At Dorchester, where the Isis joins the Thames, the pre-Roman fortifications, now unfortunately destroyed, show that at least 2000 years ago the Thames ran in its present course and at the present level. But in the lower part of its course the Thames is at present probably rather raising its bed. Mr. Layton, who has made a large collection of objects belonging to the Bronze and Stone ages, including several leaf-shaped swords from the bed of the river, principally near Kew, has observed that they generally occur at some depth, extending to 10 feet, below the present bed.

Just as the Goring gap, which the Thames has cut through the Chalk escarpment, originated at a time when the Chalk extended far to the west of its present limits, so also it is evident that the Avon could never have cut its present channel across the Clifton Downs when the surface of the area of its drainage had the present configuration. If in imagination we replace the Carboniferous Limestone and Old Red Sandstone which once occupied the gorge, the river would not take its present course,

but, as long ago pointed out by Sir H. De le Beche, would run to the sea by Nailsea.

The explanation which was suggested by Beete Jukes,[1] and which seems to me correct, is as follows: It is clear (see ante, p. 96) that the Oolites and Lias once extended far to the west. The Lias of Carlisle was no doubt continuous with that of Cardiff and of Wem, and at this time the whole country occupied by the upper waters of the Avon must have been much higher than it is at present. It was not only capped by a considerable thickness of strata, which has since been removed, but occupied a somewhat higher position in comparison with the sea-level. Hence the river was able to adopt its present course and to cut out the picturesque gorge in which it now runs.

The Humber also cuts its way through a Chalk escarpment. It crosses the Ancholme valley, and then cuts through the Chalk ridge between North and South Ferriby. It is evident, however, that when it adopted this course the Ancholme valley must have been at least 200 feet higher than it is at present, because otherwise the river would have turned southwards and run along the foot of the Chalk escarpment.

The old valley, as already mentioned (ante, p. 105), is much deeper than the present bed. A bore-hole near Sunk Island passed through 114 feet of river deposits without reaching the solid rock.[2]

[1] "On the Gorge of the Avon," *Geol. Mag.* (Dec. 1), vol. iv. 1867.

[2] Reid, *Mem. Geol. Surv.*, Holderness.

It is probable that originally the Swale, the Nidd, Aire, Calder, and Don were all independent streams working their way to the sea. They have, however, been captured by the Yorkshire Ouse and carried into the Humber.[1]

The Yorkshire Derwent has a very singular course. One branch rises close to the sea near Filey, but is blocked out by a great moraine, which forces it to run inland; and after capturing the Rye and several other streams, it falls into the Ouse, so that its waters eventually fall into the sea far to the south of its source.

The Trent, and all the large rivers of the east as far as the Bedford Ouse, are of comparatively recent origin. They have worked their way up from the sea along the softer beds of the Secondary strata. Hence their general direction from south-west to north-east, though the general slope of the country is from north-west to south-east. This was also probably the original direction of the old streams, which have been captured and cut in two, sometimes more than once, by the intercepting rivers. The lower part of the Witham, the Derby Derwent and upper Trent, the Evenlode and the Windrush, are instances of the old direction.

Again, it is probable that the Trent, as suggested by Penning,[2] instead of turning northwards at Newark, formerly flowed on to Lincoln, and through the gorge in the Jurassic escarpment, down the present

[1] Fox-Strangways, *Mem. Geol. Surv.*, "Country between York and Hull"; Reed, *Rivers of East Yorkshire.*

[2] *Mem. Geol. Surv.*, Lincoln.

Witham valley to the Wash, instead of as now to the Humber. Even recently, in time of great flood, some of the water passes that way. But why was the river diverted from its old course? Jukes-Browne suggests that the valley of the Humber was cut down to a lower level than the Trent at Lincoln, and that an old stream running into the Humber gradually cut its way back towards Lincoln. In times of flood, no doubt, the valley above Lincoln was often under water, and on one of these occasions the flood waters probably flowed over the low col, cut themselves a channel, and thus the Trent found it easier to take this course than to maintain its old channel through the Lincoln gap.[1]

In Norfolk the Ant, the Bure, and the Wensum run inland—away from the sea. The high-level gravels of Mildenhall and Lakenheath show that the river drainage was once very different from the present.

If space permitted, many other probable changes among our rivers might be mentioned.

THE AGE OF RIVERS

It follows from these considerations, not only that some of our rivers are of comparatively recent origin, while others date back to very great antiquity, but that different parts of what is now considered a single river are of very different ages and have a very different history.

Many of our river-valleys are certainly pre-glacial,

[1] Jukes-Browne, *Quar. Jour. Geol. Soc.* vol. xxxix. 1883.

and the old pre-glacial, or buried, channels, as already mentioned (ante, p. 63), are generally deeper than the existing river-beds. In some cases the surface sculpture has obvious reference, not to the present courses, but to the deeper pre-glacial valleys. The Solent is regarded by some geologists[1] as the bed of a great pre-glacial river which received the waters of the Avon and the Stour at a time when the sea-coast was considerably to the south of the present shore.

The greater part of England was dry land long before the commencement of the glacial period. If, as there is much reason to suppose, it was then submerged to the depth of some hundred feet, the valleys would to a great extent have been filled up by marine deposits. Moreover, the whole of the island north of the Thames valley was (with the exception of some of the highest hill ranges), during the glacial period, covered by a sheet of ice, so that our northern rivers may in one sense be said to be post-glacial. When, however, the ice disappeared, as the main features of the country remained the same, the rivers naturally adopted to some extent the old courses, and, speaking generally, our valleys may (though with many important exceptions) be said to be pre-glacial.

The rivers often, however, lost their way and failed to find the exact lines of their old beds. This is especially the case when they had cut narrow gorges through hard rock.

[1] Rev. W. Fox, *Geologist*, vol. v.; Codrington, *Quar. Jour. Geol. Soc.* vol. xxvi. 1870; Sir J. Evans, *Ibid.* vol. xx. 1864, and *Ancient Stone Implements.*

Take, for instance, such a narrow gorge cut in hard rock as shown in Fig. 142. Such a channel would almost inevitably be filled by drift during the glacial period, and the chances would be much against the exact spot being hit upon, and the chasm re-excavated by the post-glacial stream.

Mellard Reade has shown that the pre-glacial Mersey

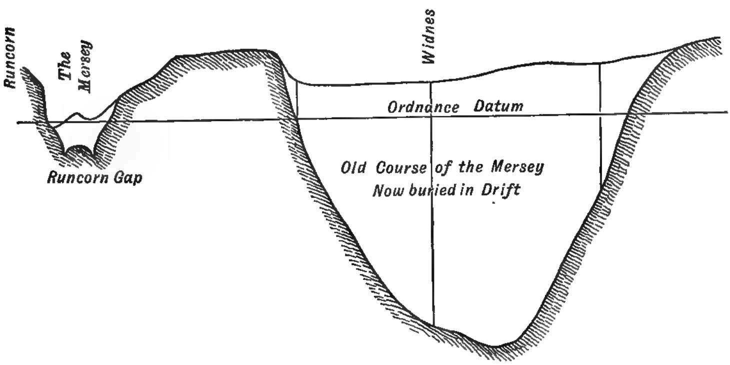


Fig. 167.—Section showing present and former course of the Mersey.

ran by Widnes (Fig. 167), where it had excavated a valley deeper than the present one at Runcorn.

It is evident that since some of our rivers began to run in their present courses the denudation of the surface must have been immense. This has been shown in the case of the Thames (ante, p. 367), the Weald rivers (ante, p. 361), the Avon, Humber, etc.

Our river system then has undergone great changes; the rivers have had many conflicts and vicissitudes; they are of venerable antiquity, have carved out mountains, filled up lakes, have changed the whole face of the country, and lowered the general surface many hundred feet since they first began to flow.

CHAPTER XII

LAKES

And thus an airy point he won,
Where, gleaming with the setting sun,
One burnish'd sheet of living gold,
Loch Katrine lay beneath him roll'd;
In all her length far winding lay,
With promontory, creek, and bay,
And islands that, empurpled bright,
Floated amid the livelier light;
And mountains, that like giants stand,
To sentinel enchanted land.[1]

In descriptions of lakes the surface level of the water is generally mentioned, but that of the bottom is perhaps even more interesting. The following table, giving the height and depth of some of our principal English lakes, is taken from Mill:[2]—

	Height.		Depth.			
			Feet.		Metres.	
	Feet.	Metres.	Max.	Mean.	Max.	Avg.
Windermere	130	39·6	219	78½	66·8	23·8
Ullswater	476	145·0	205	83	62·5	25·3
Wastwater	200	61·0	258	134½	78·6	41·0
Coniston Water	143	43·5	184	79	56·1	24·1
Crummock Water	321	98·0	144	87½	43·9	26·7
Grasmere	208	63·4	180	...	55·0	...
Ennerdale Water	368	112·5	148	62	45·1	18·9
Bassenthwaite	223	68·0	70	18	21·3	5·5
Derwentwater	244	74·5	72	18	22·0	5·5
Haweswater	694	211·5	103	39	31·4	12·0
Buttermere	329	101·0	94	54½	28·6	16·6

[1] Scott, *The Lady of the Lake.*

[2] *Geogr. Jour.* vol. vi. 1895.

The Scotch lakes are, some of them, even deeper. J. Y. Buchanan found that Lake Morar attains a depth of 180 fathoms.

It may be interesting to compare with these the corresponding figures for some of the great Swiss and Italian lakes :—

	Surface Level.	Greatest Depth.	Bottom Level.
Constance	395 metres	252 metres	143 metres
Walen	423 „	151 „	272 „
Zürich	409 „	142 „	267 „
Zug	417 „	198 „	219 „
Lucerne	437 „	214 „	223 „
Sempach	507 „	87 „	420 „
Brienz	566 „	261 „	305 „
Thun	560 „	217 „	343 „
Geneva	375 „	309 „	66 „
Neuchâtel	435 „	153 „	282 „
Bienne	434 „	74 „	360 „
Orta	290 „	143 „	147 „
Maggiore	194 „	655 „	–461 „
Como	199 „	414 „	–215 „
Lugano	266 „	288 „	– 22 „
Varese	239 „	29 „	210 „
Iseo	185 „	346 „	–161 „
Garda	65 „	346 „	–281 „

These depths are the more remarkable if we compare them with certain seas. For instance, the English Channel between Dover and Dieppe is not more than 20 fathoms in depth, and a great part of the North Sea is no deeper.

The original depth of the lakes was, moreover, even greater, because the present bottom is in every case covered by alluvium of unknown, but no doubt considerable, thickness.

The problem of the origin of lakes is by no means identical with that of rivers. We have not only to account for the general depth of the valley—this may

be due to running water—but for the exceptional basin of the lake; running water produces valleys, it tends to fill up and drain lakes.

To what then are lake-basins due?

It used to be supposed that many lakes were due to splits and fractures. I do not, however, know of any considerable English lake which can be so explained.

We may divide lakes into four classes:—

1. Lakes due to changes of level.
2. Lakes of embankment.
3. Lakes due to excavation.
4. Crater lakes.

In many cases, however, a lake may be due partly to one of these causes and partly to another, and for convenience of description they may be dealt with under nine heads:—

1. Those due to irregular accumulations of drift: these are generally small and shallow.

2. Corrie lakes.

3. Those due to moraines.

4. Those due to rockfalls, landslips, river cones, glaciers, or lava currents damming up the course of a river.

5. Loop lakes.

6. Those due to subterranean removal of soluble rock, such as salt or gypsum. These principally occur in Triassic areas.

7. Crater lakes.

8. Those due to changes in the relative level of land.
9. Those contained in hollows excavated by glaciers.

1. As regards those due to irregular accumulations of drift, we find here and there on the earth's surface districts sprinkled with innumerable shallow lakes of all sizes, down to mere pools. Such, for instance, occur in the district of Le Pays de Dombes between the Rhone and the Saône, that of La Sologne near Orleans, in parts of North America, in Finland, and elsewhere. Such lakes are, as a rule, quite shallow.

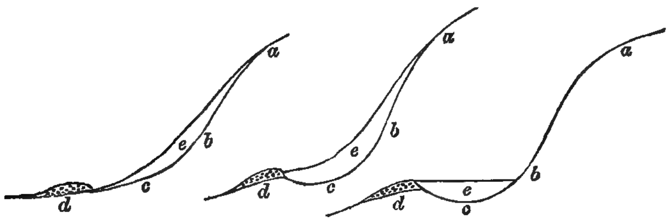


Fig. 168. Fig. 169. Fig 170.

Diagrams to illustrate Corrie Lakes.

They are due to the fact of these regions having been covered by sheets of ice which strewed the land with irregular masses of clay, gravel, and sand, on a stratum impervious to water, either of hard rock such as granite or gneiss, or of clay, and where there is not sufficient inclination to throw it off. Some of the Cheshire and Holderness meres and many mountain tarns are attributable to this class.

2. Corrie[1] lakes may be explained as follows :—Let us assume a slope (Fig. 168, *abcd*) on which snow and ice (*e*) accumulate.

The rocks and fragments falling from the heights

[1] From the Celtic "coire," a caldron.

would accumulate at *d*. Moreover, the ice would tend to form a hollow at *c* (Fig. 169), where the pressure would be greatest.

If subsequently the snow and ice melted, water would accumulate in the hollow (Fig. 170); and lakes thus formed are common in mountainous districts, where they have a special name—corrie lakes in Scotland, oules in the Pyrenees, botn in Norway, karwannen in the German Alps, etc.

3. A third class of lakes is that due to river-valleys having been dammed up by the moraines of ancient glaciers.

To this cause are due the lakes of Zürich (in part), of Hallwyl, of Sempach, several of the Italian lakes (Iseo, Orta), of the Norwegian lakes, and many others. In fact, most of the valleys descending from the Alps have, or have had, a lake where they open on to the plain.

In our own country, amongst the lakes said to be due to moraine dams are Glasllyn, Llyn Goch, and others in North Wales, Llyn Carw and Llyn-y-vau[1] (Carmarthen), Llyn Cwm Llwch near the Brecon Van,[2] and Bleawater Tarn, near Haweswater, considered by many to be the finest tarn in the Lake District. It is nearly circular; the inner semicircle is a fine range of cliffs, rising almost perpendicularly for several hundred feet to the ridge of High Street, and the outer part of the circle is said to be an old moraine.

4. The fourth class of lakes were once much more numerous than at present. They are essentially

[1] Symonds, *The Severn Straits*. [2] *Ibid.*, *Records of the Rocks*.

temporary. In our own country I may mention Goat's Water on Coniston Old Man, and Smallwater near Haweswater; the margins of such an ice-dammed lake form the celebrated "parallel roads of Glenroy." The Lake of Tiberias is said to be dammed up by a lava current.

5. Loop lakes occur along the course of many large rivers. The stream begins (see ante, p. 300) by winding in a loop which almost brings it back to the same point. The narrow neck is at last cut through and the loop remains as a dead river-channel, or "Mortlake." Again, when an island is formed in mid-channel, one of the side streams is often cut off, and forms a curved piece of standing water.

6. Subsidence lakes, as already mentioned, occur principally in Triassic areas. The gypsum or salt is dissolved away in places, and eventually the ground gives way, leaving funnel-shaped hollows.

Such a pool was actually formed near the village of Orcier in the Chablais in the year 1860. There had previously been a strong spring giving rise to a stream. Suddenly the ground fell in, forming a pond about 20 metres long and 8 wide. Three fine chestnut trees were engulfed, and the pool was so deep that at 20 metres no bottom was found, nor were even the tops of the trees touched.[1]

Some of our Cheshire meres are due to the same cause.

7. Lakes occupying craters are far from infrequent in volcanic regions, as for instance in the Auvergne, the celebrated Lake Avernus in the district of Naples,

[1] Favre, *Rech. Géol.* vol. ii.

and the Maare of the Eifel. "Crater Lake" in Oregon is circular in form, about 4 miles across, and 2000 feet deep. There are, however, no crater lakes in England.

8 and 9. There has been and still is much difference of opinion whether the hollows occupied by the larger lakes on the continent and in this country are due to relative movements of the earth, to dams of glacial deposits, or to erosion by glaciers.

Ramsay and Tyndall maintained that they were rock basins excavated by glaciers.

"That glaciers rub down rocks," says Sir A. Geikie, "is demonstrated by the *roches moutonnées* which they leave behind them."

That rock-tarns on bare ice-worn plateaus are hollows of erosion due to the action of ice is generally admitted. They are dispersed, for instance, all over, and occur by thousands in, the Scotch Highlands and the Hebrides. The surface of the gneiss districts sometimes consists almost as much of water as of land. On the other hand, there are strong reasons against regarding glaciers as the main agents in the formation of the great continental lakes; these have been pointed out with great force by Ball and Bonney, and geologists are by no means agreed on the subject.

That the North Country and Welsh lakes are drowned river-valleys no one will deny. Their narrow winding courses and general appearance (Fig. 171) leave no room for doubt on this point. But the difficulty is to account for the dam at the lower end.

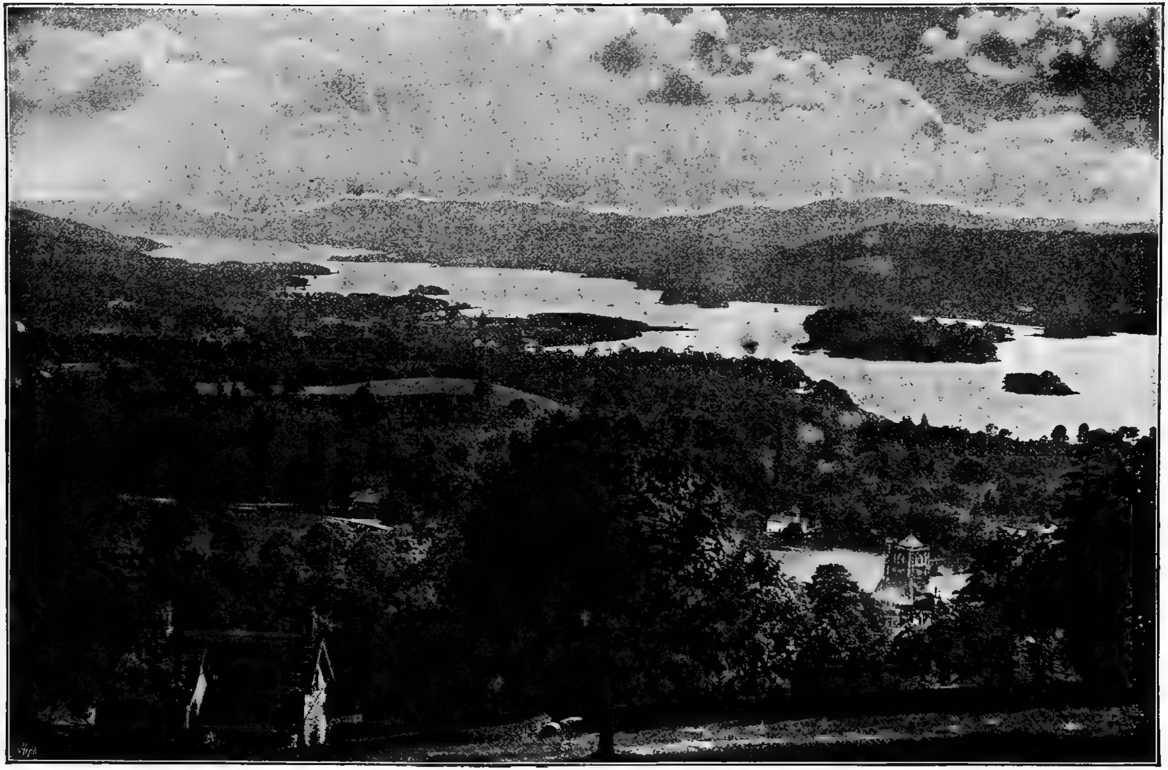


Fig. 171.—Lake Windermere.

If they were once river-valleys the slope must have been continuous down to the sea-level, as shown in

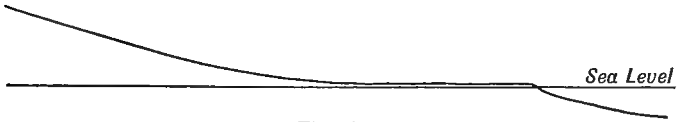


Fig. 172.

Fig. 172. A river may and does wind, the inclination of its bed may and does change frequently; but

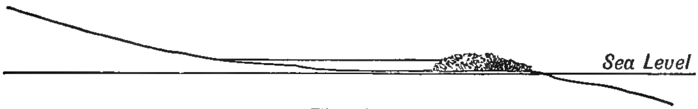


Fig. 173.

however much the slope from the source to the mouth may vary it must sink continuously, so far as it is due

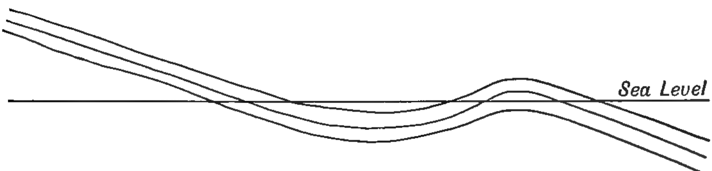


Fig. 174.

to the action of the river itself. The valley is a river-valley; to convert it into a lake there must

Fig. 175.

be a dam, and the problem is to account for the dam.

The formation of our large lakes might be explained in three ways.

1. That the site of the lake may have sunk relatively to the land beyond, as shown in Fig. 174.

The majority of Continental geologists have come gradually to the opinion that while the valleys occupied by the great Swiss and Italian lakes were mainly excavated by running water, the lakes themselves are due to changes of level, which have raised parts of the valleys as compared with the river courses nearer the mountains.

Heim has suggested that the compression which elevated the Swiss mountains, and piled more than double the original weight on this portion of the earth's surface, led to the formation of the great lakes. The mountain mass thus concentrated on a comparatively small area would, he considers, from its enormous weight, tend to sink somewhat into the softer magma below, which, of course, would have had in this respect the same effect as if the surrounding country had risen. The result would be to dam up the rivers and fill the valleys. For instance, in the Lake of Lucerne the bottom of the Bay of Uri is almost flat; it is evidently a river-valley which has been filled with water.

Passing to other countries, the case of the Dead Sea is very suggestive. From the lower end a long depression leads southwards; it is evident that the Jordan once ran into the Gulf of Akaba and so to the Red Sea, and that a subsequent change of level has created the Dead Sea, which has a depth of 396 metres below the ocean-level.

The great American lakes are also probably due

to differences of elevation. Round Lake Ontario, for instance, there is a raised beach, which at the western end of the lake is 110 metres above the sea-level, but rises towards the east and north, until near Fine it reaches an elevation of nearly 300 metres. As this terrace must have originally been horizontal, we have here a lake barrier, due to a difference of elevation, amounting to over 180 metres. There can therefore be little doubt that the great American lakes are due to earth movements, which indeed there is reason to believe have not yet wholly ceased.

There can be, of course, no doubt that differences of level have been caused by earth movements. Oldham, for instance, has observed such a case in the Garo Hills, India, after the earthquake of June 1897, and many others are on record.

In the case of our British lakes, however, we have no conclusive evidence of any changes of level. Such changes indeed are easy to suggest but difficult to prove.

2. The second view is that moraine matter may have been deposited at the lower ends and irregularly along what are now the bottoms of the lakes (Fig. 173). Lyell long ago pointed out that "if a great glacier fill the lower part of the valley, all the conditions of the problem are altered. Instead of the mud, sand, and stones drifted down from the higher regions being left behind in the incipient basin, they all travel onwards in the shape of moraines on the top of the ice, passing over and beyond the new depression, so

that when, at the end of fifty or a thousand centuries, the glacier melts, a large and deep basin representing the difference in the movement of two adjoining mountain areas, namely, the central and the circumferential, is for the first time rendered visible."[1] The streams which drain some of our lakes (Ullswater and Haweswater, for instance) are said to run out over drift. These lakes then are certainly, in part at any rate, due to glacial deposits. Some geologists, indeed, maintain that this is the case with all our larger lakes. They deny to glaciers any power of excavation, and believe that the lakes are all dammed back by glacial drift.[2] It is indeed admitted that in many cases the present outflow is over live rock, but it is suggested that in each of these cases the present is not the original place of outflow, and that the original outlet has been dammed up. I have had the pleasure of visiting several of these with Mr. Marr, and certainly there were in some cases indications of an older valley not far from the present exit. In Windermere itself even a casual glance at the map suggests that the original outflow was down the Cartmel valley, and that the present eccentric course of the water by the gorge of the Leven is due to the natural exit being blocked by drift, which raised the level of the water until it found an outflow on one side.

This is certainly a possible explanation, and it can hardly be doubted that some lakes are thus caused. Fig. 176 represents the beautiful waterfall of Scale

[1] *Antiquity of Man.* [2] Marr, *Scientific Study of Scenery.*

Fig. 176.—Scale Foss.

Foss, and shows how narrow is the channel through which the water escapes. It might easily be dammed by drift, and the valley would then become a lake, which might be supposed to be a true rock-basin. More or less similar cases are shown in Figs. 116, p. 294; 138, p. 330; and 142, p. 333.

They prove, at any rate, that careful examination is necessary before it can safely be assumed that any given hollow is a true rock-basin.

3. According to the third view, it is considered that the cup of the lake is mainly due to erosion by the ancient glaciers (Fig. 175), and, though of course the inequalities of the bottom are partly owing to the irregular deposit of drift, that the glaciers, which undoubtedly at one time occupied the valleys, eroded the bottoms of the valleys somewhat irregularly, excavating them more effectively where the pressure was greatest.

It must be remembered that in many of our valleys the pressure of the ice on its bed must have been very great. The ice must have been in places at least 1500 feet in thickness.

The pressure exercised by a glacier on its bed will depend partly on the thickness of the ice and partly on the inclination.

"Taking the case of a glacier," says Tyndall, "300 metres deep (and some of the older ones were probably three times this depth), and allowing 12·20 metres of ice to an atmosphere, we find that on every square yard of its bed such a glacier presses with a weight of 486,000 lbs. With a vertical pressure of

this amount the glacier is urged down its valley by the pressure from behind."[1]

Indeed, it is obvious that a glacier many hundred, or in some cases several thousand, feet in thickness, must exercise great pressure on the bed over which it travels. We see this from the striæ and grooves on the solid rocks, and the fine mud which is carried down by glacial streams. If the explanation of hanging valleys suggested on p. 348 be correct, it is evident that the excavation of the valley from ACB to AEB (Fig. 156) must have been effected by the action of the ice.

The diminution in the rapidity of motion of a glacier at the sides and near the bottom, which has been relied on as evidence that glaciers cannot excavate, shows on the contrary how great is the pressure.

Just as a river tends to make its course through an alluvial plain more and more sinuous by attacking the outside of each curve, so does a glacier exert its main erosive power at, or near, the bottom of a slope where its direction changes, and where the thrust and pressure upon its bed are at a maximum. In this way may be produced a valley which descends to the lowlands in a series of giant steps, the upper ends of which are often occupied by lakes.

The question has been sometimes discussed as if the point at issue were whether rivers or glaciers were the more effective as excavators. But this is not so.

Even those who consider that lakes are in many cases due to glaciers might yet admit that rivers have greater power of erosion. There is, however,

[1] Tyndall, "Conformation of the Alps," *Phil. Mag.* vol. xxviii. 1864.

an essential difference in the mode of action. Rivers tend to regularise their beds; they drain, but cannot form, lakes. As Playfair long ago pointed out,[1] a lake is but a temporary condition of a part of a river. Owing in fact to rivers, lakes are mere temporary incidents. The tendency of running waters is to cut through any projection, so that finally its course assumes some such curve as that in Fig. 108, p. 287, from the source to its entrance into the sea.

The existence of hard ridges (Fig. 177) would not

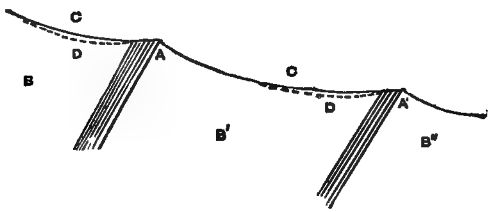


Fig. 177.—Diagram to illustrate the action of Rivers and Glaciers. AA′, Hard ridges; BB′B″, softer strata; CC, slope of running water; DD, slope of ice.

give rise to lakes—it would only delay the excavation of the valley; above each the slope would become very gentle, but no actual basin could be formed, and we should have some such section as shown by the continuous line in Fig. 177. The action of a glacier is different; it picks out as it were the softer places, and under similar circumstances basins might be formed above the harder ridges, as shown in the dotted lines DD.

"There are few geologists," says Deeley, "who have visited glaciated districts who have not been struck by the great difference in the appearance of

[1] Playfair's *Works*, vol. i.

valleys viewed from the two aspects up and down. Looking down, all the surfaces and outlines are seen to be rounded, whereas, looking up, rough, rocky, and irregular surfaces everywhere meet the eye.”

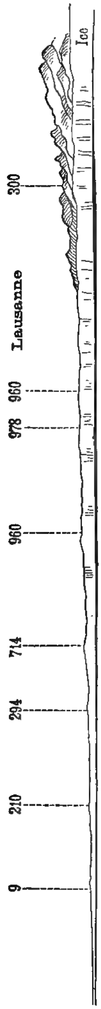


Fig. 178.—Diagram section along the Lake of Geneva during the glacial period. The dark line shows the relative depth of the water.

This is quite true, and exhibits on a large scale the phenomena of “crag and tail,” which has already been described (ante, p. 50).

The deepest part of the Cumberland and Westmoreland lakes is not, as we should expect on the “dam” theory, near the lowest end, but either at the narrowest part or where the inclination becomes less, or where there is a belt of softer strata; in all three cases just where a glacier would produce most effect.

For instance, in four of the lakes the deepest part is in the upper portion, and in one only, that which is now divided into Buttermere and Crummock, is it at the lower end, and even here there is an important depression at the head. In Derwentwater and Wastwater the narrowest part is the deepest.

Moreover, although it is said, and said truly, that many lakes are very deep, still in relation to the size the depth is quite insignificant. This is the case, for instance, even with the Lake of Geneva itself (Fig. 178).

As regards our own lakes, Wastwater is 200 feet

above the sea-level and 258 feet deep, Windermere 130 feet above the sea and 220 feet deep, Coniston 143 feet above the sea and 184 feet deep, so that all these lakes are deeper than the present sea-level.

Yet, if we compare these depths, great as they are, with the other dimensions of the lakes, we shall find, perhaps to our surprise, that they are after all mere films of water (Figs. 178, 179).

The fact is that many of these lake-basins would remain almost unnoticed if it were not for the presence of the water.

If, moreover, we follow up almost any Lake District valley, we find a more or less numerous series of depressions separated by ridges.

Fig. 179.—Diagrammatic figure showing the relative length and depth of Windermere.

For instance, above Windermere is Rydal Water, separated by a rocky gorge from Grasmere; or if we go up the Brathay we come first to the valley at Skelwith, then the rocky gorge of Skelwith Foss (Fig. 138, p. 330), then Elterwater, above which is another gorge, and then the long winding plain of Upper Langdale. In Scotland, moreover, we are assured that true rock-basins are very numerous.

River action alone, indeed, could not give rise to such depressions. It would account for the plain, but not for the hollow.

At any rate, it is clear that glaciers exercise a certain erosive action, and that this would be more effective at certain points than at others—for instance, where the

underlying stratum was more easily affected, or where the pressure was greatest. Hollows would thus be produced, and to these lakes must in some cases be due. On the whole, then, I am disposed to refer some of our lakes to the erosive action of glaciers.

When, however, we attempt to apply these general considerations to particular instances, we must, I think, admit that in most cases the question cannot be finally decided until we have more detailed information as to the nature of the deposits and the position of the living rock at the exit of the lakes.

BALA LAKE

Sir A. Ramsay regarded Bala Lake as a clear case of a rock-basin. "Two miles down the river," he says, "towards Llandrillo, the rocky bottom of the river is from 500 to 510 feet above the sea, while the bottom of the lake is only 470 feet above the level; and even beyond this at the ferry, half-way between Corwen and Llangollen, 14 miles in a straight line E.N.E. of the lake, the rocky bottom of the river is about 475 feet above the sea, or 5 feet above the bottom of Bala Lake"; and he concluded that "as there is not, and never could have been, any other possible outlet for the water of the lake than the channel of the Dee, it is quite certain that it lies in a rock-bound basin." It is, however, by no means so clear that the outlet of the lake was always down the valley of the Dee.

The origin of the lake is a very complex question, and further examination is required before any final

conclusion can be arrived at. It has been suggested that the original outlet was to the south-west, and that the present overflow to the north-east is comparatively recent. This view has recently been advocated by P. Lake.[1] The valley is no doubt a tectonic valley. There is a great fault which extends from the coast at Dysynni, north of the River Dovey, and extends to the north-west by Tal-y-llyn and Moel Dhu, along the Bala Lake, and so into Cheshire. The whole district has been much disturbed, and this, though the principal, is only one of many faults. Though, no doubt, the surface has been much modified by denudation, Lake observes that these faults would of themselves give rise to valleys very similar to those which now exist. Moreover, while most lakes have an alluvial plain at the upper end, Bala has one at both; but this is not so conclusive as it might at first sight appear, because the alluvial plain at the lower end is certainly in part, and may be entirely, due to the Afon Gelyn.

There are, moreover, other considerations which point to the same conclusion. The floor of the lake slopes not from south-west to north-east, but from north-east to south-west. Moreover, the lake does not lie in the direction of the Vale of Edeyrnion (the valley of the Dee between Llandderfel and Corwen), but in a well-marked valley which runs from the sea at Barmouth to Bala, and this would follow approximately the line of the road to Corwen, while the Dee diverges and runs through a narrow gorge by Llan-

[1] *Geol. Mag.* vol. vii. 1900.

dderfel. To the south-west, along what was according to this supposition the old course of the river, the valley is blocked by drift, and we have as yet no conclusive evidence that the solid rock underlying the valley is anywhere higher than the bottom of the lake.

There is no strong inherent improbability that the course of the river has been reversed, for no great change would be required, and we can hardly suppose that ever since the valleys were formed the whole country has remained fixed and immovable.

It is clear that Bala Lake belongs to the same valley as the River Wnion, and there seem strong reasons, not yet however amounting to proof, that, as Lake supposes, the waters of the Bala valley formerly overflowed south-west and fell into the sea at Barmouth.

TARNS

Some tarns are hollows in the irregular surface of drift, others are true rock-basins, though some eminent authorities maintain that most, if not all, of them are dammed by glacial drift.

Every one indeed will admit that many tarns are, at any rate in part, dammed by moraine matter. Such tarns will, however, enjoy but a short life if the overflow follows the old course, as the loose drift will be ere long cut through. If, however, the new channel does not lie exactly over the bottom of the old valley, the stream may, and no doubt often would, hit upon some slight depression in the solid rock; denudation would then be retarded, and the tarn might be much

more permanent. Marr, indeed, believes that most of the tarns are dammed up by drift, and are not true rock-basins. He refers especially to the case of Burnmoor Tarn. Here he thought at first that he had found a true rock-basin. It appears to be bound by rock all round; but on careful examination he found in one place a drift-filled gorge, running down the cliff from top to base, and only about ten paces across. Through this the upper part of Miterdale, he considers, was obviously once drained. It is now dry, and the Mite runs below.

He also calls attention[1] to the case of Hard Tarn in Ruthwaite Cove on Helvellyn. It is small and shallow, surrounded on all sides by rock except at the main exit, where the water runs over the screes which have given rise to the tarn. There is, however, a low lip of rock over which some water escapes in wet weather. He suggests that the screes are increasing, and that eventually this which is now only the wet weather exit will become the regular place of outflow. This has, he believes, actually occurred at the Ffynnon Felen, in Cwm Glas on Snowdon, as described by Watts.[2] Dakyns,[3] on the contrary, regards these as true rock-basins. He admits that Glaslyn, for instance, is bordered by drift on the south, but points out that at the old mill, seventy yards from the lake, solid rock extends completely across the valley. This is 40 feet below the level of the lake, and hence if,

[1] *Scientific Study of Scenery.*

[2] "Notes on some Tarns near Snowdon," *Rep. Brit. Ass.* 1895.

[3] *Geol. Mag.* (Dec. 4), vol. vii. 1900.

as is probable, it is more than 40 feet deep, the lower part must constitute a true rock-basin.

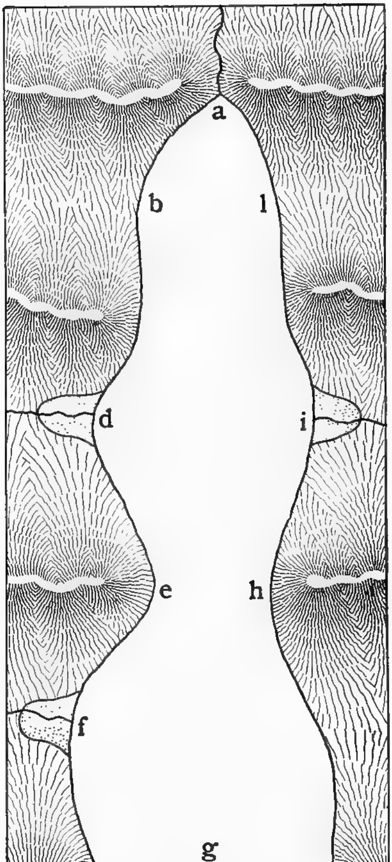


Fig. 180.—Early stage of a Lake.

At Llyn Llydaw, again, solid rock exists all round the lake and across the outlet from 25 to 30 feet below the water-level; and as the lake is said to be 200 feet deep, it must also be a rock-basin. At Glaslyn also he asserts that there is solid rock all round the lake.

THE OUTLINES OF LAKES

Directly a lake is formed the outline will begin to alter. If, for instance, we imagine a valley gradually widening downwards towards the sea, but broader when it is joined by lateral valleys, and narrowed here and there by spurs of the hills, we might have an outline something like Fig. 180.

Now, suppose that, either by the lower end being raised or by its being blocked up, the valley is

turned into a lake. The shores at *b*, *e*, *h*, and *l* would alter for a long time very little. If anything, the waves might slightly erode the shore, and the

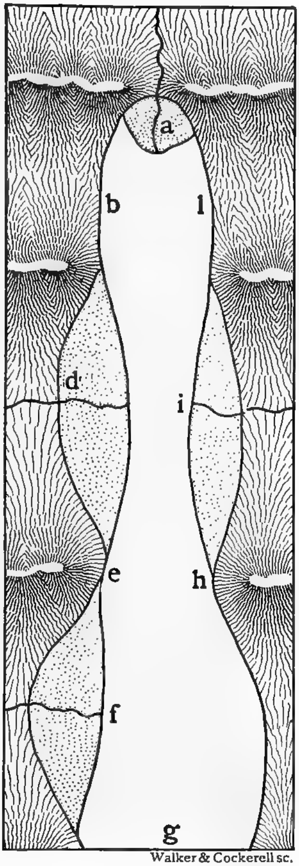


Fig. 181.—Second stage of Fig. 180.

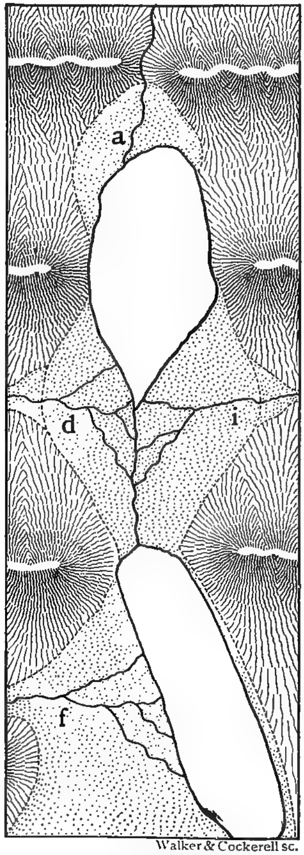


Fig. 182.—Third stage of Fig. 180.

lake might be somewhat widened. On the other hand, the streams coming down the valleys at *a*, *d*, *f*, and *i* would at once begin to form deltas. Thus (Fig. 181) we should have at *a* the tract of flat land at the upper end characterising so many of our lakes. The

deltas would continue to grow, and the lake at *d* and *i* would become narrower and narrower until, as shown

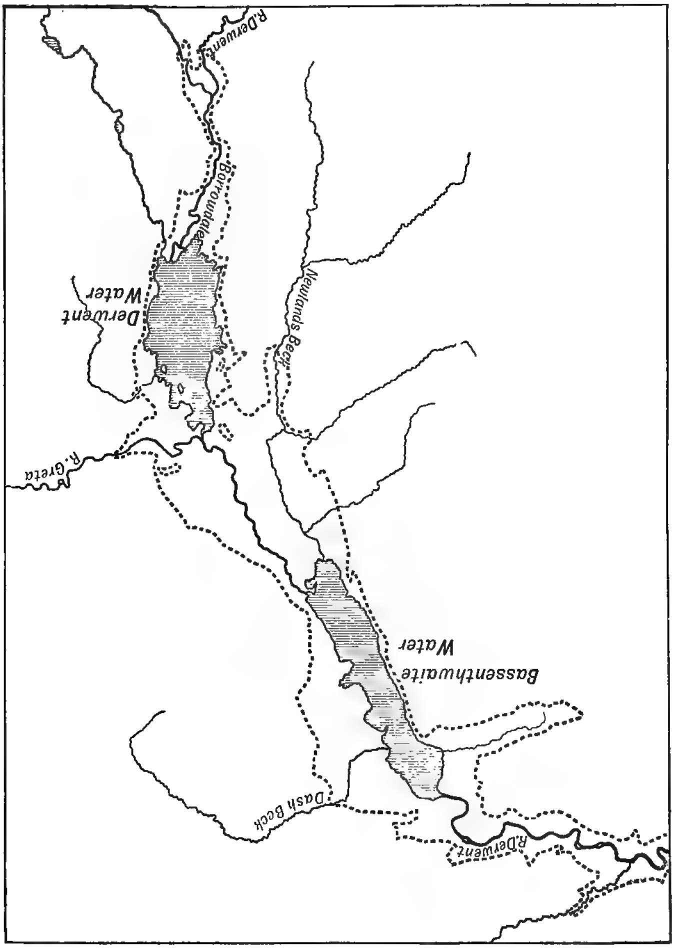


Fig. 183.—Sketch-map of the Derwentwater and Bassenthwaite Valley.

in Fig. 182, the outlines would be entirely altered, the concave curves of the original lateral valleys becoming convex deltas, and the parts of the lake

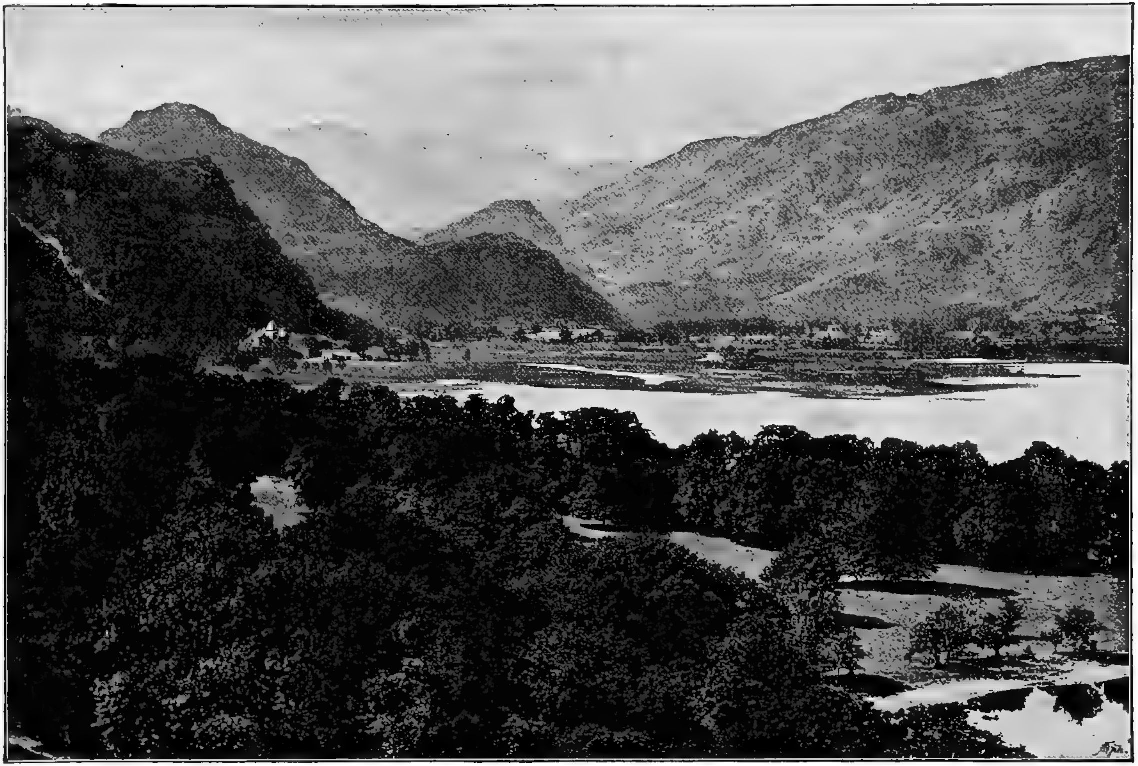


Fig. 184.—Upper end of Derwentwater.

which were originally widest becoming narrower and narrower; eventually the deltas of the lateral streams might unite and divide the original lake into two. From the upper lake a stream would run down the valley into the lower lake. It would also at once begin forming a delta of its own. In the meantime the stream *f* would also have been enlarging its own delta and filling up one side of the lower lake. Thus we should have a narrow lower lake and a broader upper lake—narrow where it was originally broadest, widest where it was originally the most narrow.

This is something like what has actually happened, for instance, on the River Derwent. The valley being raised or dammed above Cockermouth, a large lake was formed. Fig. 183 represents the valley from the foot of Bassenthwaite up to near Lodore. The dotted lines represent the 500 feet level. The broadest part of the depression is between Braithwaite and Keswick or Armathwaite; it is narrowest between Brandelhow and Castlerigg Fell, and again between Barf and Crossthwaite.

The Greta and Newlands Beck, corresponding to the streams *i* and *d* in our diagrams, have made a flat plain which has separated Bassenthwaite from Derwentwater. Moreover, the broadest part of Derwentwater, that between Brandelhow and Castlerigg Fell, corresponds to the comparatively narrow part of the valley; while the gradually narrowing lower end of the lake corresponds to the wide part of the valley between Braithwaite and Keswick.

It may indeed be said as a general rule that lakes

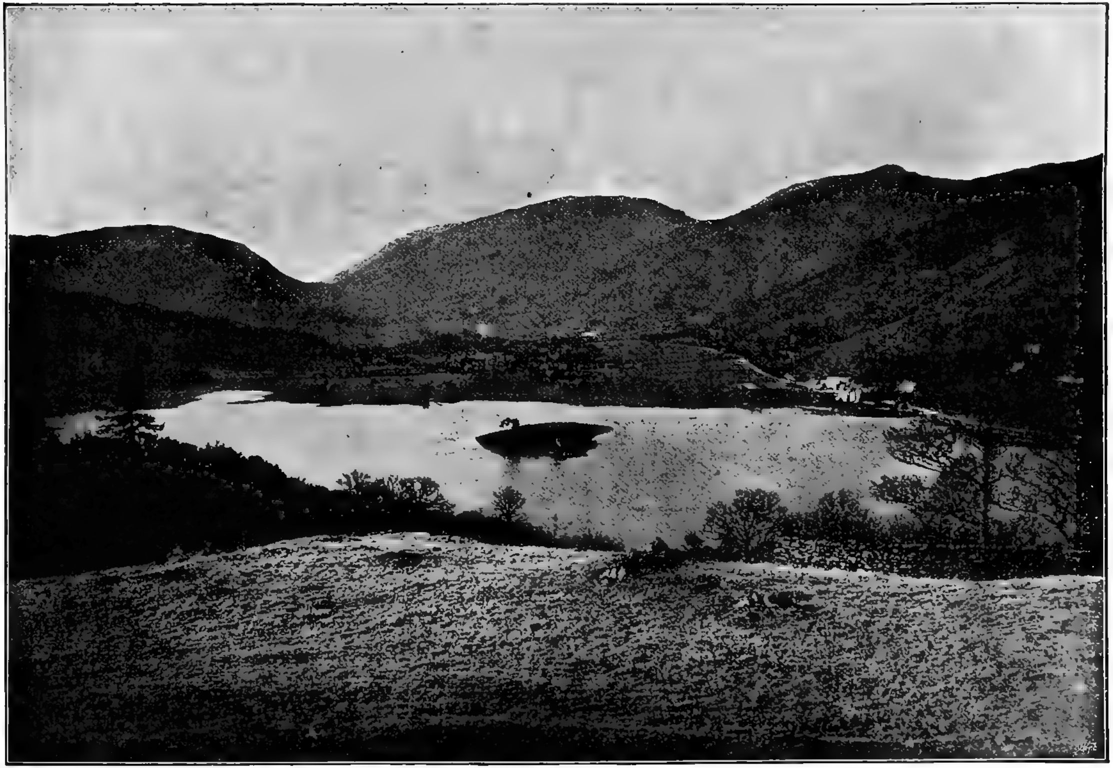


Fig. 185.—Grasmere.

are being filled up by the deposits of the rivers that run into them. Hence the flat plains at the head of Wastwater, Ennerdale, Buttermere, Derwentwater (Fig. 184), Thirlmere, Ullswater, Windermere (Fig. 186), Coniston—indeed, of all our lakes. Haweswater is almost cut in two by the great delta of Measand Beck. Hence also the square outline at the head of several of our lakes, as, for instance, of Ennerdale, Crummock Water, Buttermere, Brothers Water, Ullswater, etc. Bassenthwaite has been cut off from Derwentwater and Crummock Water from Buttermere.

Fig. 130, p. 313, represents a lateral delta, that of the Aira Beck on Ullswater.

Let us also look at the case of Windermere (Fig. 171, p. 389). The long narrow form is due to its being a drowned river-valley; the curves also are those of a large river; the flat ground at the upper end is the delta of the combined Brathay and Rothay; the flat whale-backed islands are rocks rounded by the glacier which once filled the valley; the Flagstaff Hill and many other rounded mounds are morainic matter left by the glacier in its retreat; the narrowing of the lake opposite Red Nab, Lingholm, and Rawlinson Nab is due to the deltas of the Troutbeck and Cunsey Beck; the flat low ground at the foot of the lake to Cartmel is probably the ancient river-valley, which has been choked by glacial deposits, thus damming up the lake till it found a lateral overflow by the present course of the Leven.

Lastly, Pullwyke Bay remains to be considered. This is due to a belt of softer strata which crosses the

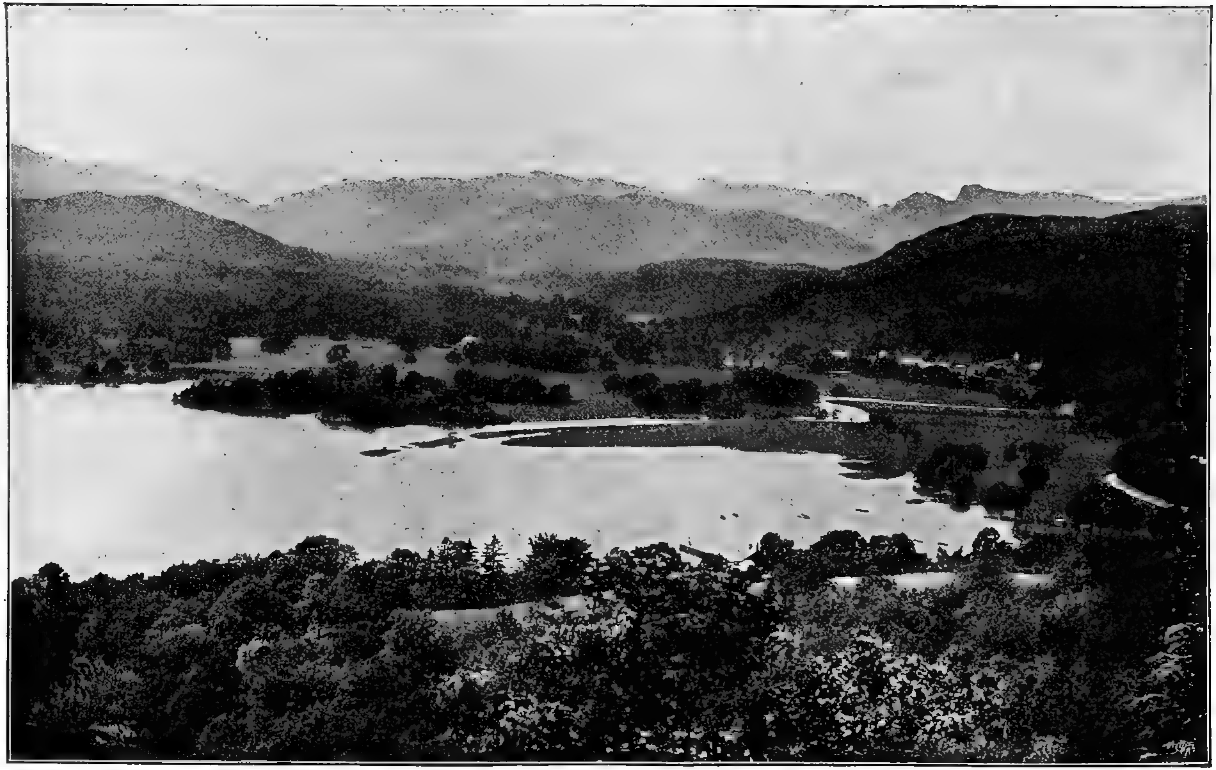


Fig. 186.—Upper end of Lake Windermere.

lake diagonally along the direction of the Pullbeck. There is no corresponding bay exactly opposite, because a fault has carried the softer belt of rocks somewhat farther south, nearly to the Low Wood Hotel. On this side of the lake, however, the bay has been nearly filled up by the Holbeck brook. The Pullbeck has not been able to fill up the Pullwyke Bay because it drains a smaller area and has a smaller fall. The valley is in fact abruptly cut off about two miles from the lake by the Blackfell. This is due to a fault and a block of the hard volcanic rocks which has been thrust southwards for about two miles.

The guide-books usually say that Loweswater "is an exception to the general rule, that the best view of a lake is obtained when looking from the lower to the higher end" (Jenkinson). The fact is, however, that Loweswater is the only one of the larger Cumberland and Westmoreland lakes which drains towards the centre of the district. Hence the mountains are towards what is now the lower end of the lake. There is, however, some reason to suppose that the present arrangement is comparatively modern. It will be observed that the lake is not only exceptional in the point already alluded to, but also in the fact that there is a tract of low ground at the *foot* of the lake. This also suggests that the drainage has been reversed, and that the water formerly entered the lake at what is now its lower end.

It has long been known that the bottoms of many of the lakes now form plains, as flat as the

floor of a temple. This feature has been strikingly brought out by Mill.[1] Buttermere "forms a simple trough, with steeply sloping walls and a nearly flat floor." The deepest part, 94 feet, is less than $\frac{1}{6}$ of a mile from the head, and here "is a nearly rectangular plain 400 yards by 300, the undulations of which nowhere exceed 4 feet." Crummock is 144 feet deep, and 208 acres are below 125 feet. The bottom of Wastwater is a long level plain undulating from a depth of 250 to 258 feet. Ennerdale is a trough "with steeply sloping sides and a flat floor." The middle reach of Ullswater is a long, flat-bottomed trough. In Windermere, opposite Wray Castle, an area 3 miles long and nearly $\frac{1}{3}$ of a mile wide forms a flat, gently undulating plain from 200 to 219 feet in depth, or nearly 100 feet below the sea-level.

This remarkable flatness is probably due to the fact of these being the plains of old river-valleys, further levelled, no doubt, by the deposition of fine mud, which is doubtless in some places of considerable thickness, and indicates that the lakes, though so recent geologically, are very ancient if we measure their age in years.

While rivers are permanent, lakes are essentially temporary. Many parts of the country are dotted with the sites of lakes which have been either filled up from above or drained from below. Of the many Holderness meres Hornsea remains almost alone; in East Anglia many of the towns are built on what were once islands.

[1] Mill, *Geog. Jour.* vol. vi. 1895.

Numerous as lakes still are in Cumberland, Westmoreland, and parts of Wales, it is evident that they are a mere fraction of those which once existed. In fact, we find every gradation from deep lakes, by shallow pools, peat-mosses and marshes, to the numerous flat surfaces which attest the existence of former lakes.

THE BROADS

Another class of lakes are those which are known as the Broads. They are a very distinctive feature of East Anglian, and especially of Norfolk, scenery.

The marsh lands, which form extensive tracts near the mouths of the principal rivers, were originally estuaries.[1] Gradually they became contracted by the growth of sandbanks. That on which Yarmouth is built did not become sufficiently firm to support human dwellings until the year 1008. It was then separated from Caistor by a channel called Grubbs Haven, which silted up in the time of Edward III. The marshes themselves remain in many cases below the level of the sea, and are flooded from time to time, especially during the winter months. This gradually tends to raise their level by a process of warping. The upper courses of the Norfolk rivers have for the most part been converted into waterways or canals of still water, with falls of 3 or 4 feet every here and there, which have been utilised for mills. Their sluggishness is perhaps partly due to the fact that the encroachments of the

[1] Woodward, *Mem. Geol. Sur.*, Norwich.

sea have deprived them of a considerable part of their drainage area.

They are shallow fresh-water lakes, as a rule about 8 feet, and I believe never more than 15 feet, in depth, sometimes in the direct course of the streams, but more often now separated from them by a bank of reeds, sedges, rushes, water-grasses, and other plants,

Fig. 187.—View in the district of the Broads, Norfolk.

through which one or more narrow channels have been cut. Hickling Broad is so shallow that it is possible to walk almost everywhere on its gravelly bottom. The Broads are becoming slowly filled up by the growth of water-plants and the deposit of sediment. In the valleys of the Bure, Yare, and Waveney there are, however, still over thirty of these Broads.

The Broads rest on drift and alluvium, which

attain a depth of some 150 feet. They were probably formed by bars being thrown across the outlets of the valleys in which they lie, during the silting up of the main channels. They must, therefore, date back to the time when these channels formed branches of the estuary. The bottom of the Broads is in several cases at or even below the sea-level. Even as lately as the time of the Saxons Norwich was on an estuary.[1]

The Broads are not, apparently, of any great antiquity, nor, it is probable, will they long survive. They are gradually diminishing in area and in depth, in some cases, according to the Rev. J. Gunn, at the rate of a foot in twenty years. This is in no small degree due to the rapid growth of marsh-plants. In some places where fifty years ago there were marshes and swamps, and even where boats could sail, cattle now graze.[2]

Besides the permanent Broads, parts of the low-lands sometimes are, and no doubt formerly much oftener were, flooded, forming so to say temporary Broads. Thus, in the autumn of 1878 the Staithe at Millgate, Aylsham, was flooded; there was from 3 to 4 feet of water in the main road leading to North Walsham, and for some time the meadows on both sides of Aylsham were submerged. The low-lying fens near Patling and Stalham are often flooded in winter.[3]

[1] Woodward, *Mem. Geol. Sur.*, Norwich; see also Marr, *Scientific Study of Scenery*.

[2] *Mem. Geol. Surv.*, Norfolk; White's *Hist. of the County*.

[3] Reid, *Mem. Geol. Sur.*, Cromer.

COLOUR OF LAKES

Lakes owe much of their charm to their great limpidity and exquisite colouring. Their clearness is due to the fact that the mud brought down by the streams is deposited near their mouths and does not extend far into the lake.

In colour they differ greatly. Over and above the tints due to changes in the sky, many lakes have a very distinct colour of their own. The Lake of Geneva is intensely blue, but the Lake of Lucel in the Val d'Hérens is perhaps the bluest of all. Glaslyn and Llyn-dur-Arddhu on Snowdon are indigo. Many are bluish-green, green, or yellowish, while some are quite colourless.

What is the reason of these differences?

The blueness is not due to, though it may be enhanced by, the reflection of the sky. Pure water in sufficient quantity is an exquisite blue, and various suggestions have been made to account for the green colour of some lakes. The most probable explanation appears to be that suggested by Wettstein, and ably supported by Forel,[1] namely, that the blue is turned into green by minute quantities of organic matter in solution. Forel took water from several lakes and thoroughly filtered them, but they retained their colour, showing that it was not due to particles in suspension. He then took a block of peat, and infused it in water, thus obtaining a yellow solution.

[1] *Le Léman*, vol. ii.

By adding a small quantity of this to the blue water of the Lake of Geneva, he was able to obtain a green colour, exactly similar to that of the Lake of Lucerne.

He refers as a test case to the sister lakes of Achensee and Tegernsee in the Tyrol. The basin of the Achensee is free from peat, in that of the Tegernsee peat-mosses cover a large space. The former is a brilliant blue, the latter a lovely green. He concludes, therefore, with Wettstein, that the bluest lakes are those which are the purest; while green lakes contain also a minute quantity of vegetable matter, or peat, in solution.

This is, however, by no means the only cause to which water owes a green hue. Shallow water over yellowish sand is green by the reflection of the yellow light from the bottom. Again, after storms the water is often rendered thick and turbid. After the coarser mud has subsided the finer impalpable particles give the water a greenish hue, which, however, is only temporary, though it may last for some time. Finally, the water is sometimes coloured green in patches by microscopic algæ.

But though the blueness of lakes and seas is not entirely owing to reflection from the blue sky, the brilliancy, beauty, and variety of tone and tints, the play of colour to ultramarine and violet, the constant changes and patterns varying with every breath of wind,—in short, the life and glory and beauty of the lakes,—are entirely due to the light of the sun.

Perhaps I ought to say a word about the so-called

floating islands. One appears occasionally in Derwentwater, and they are not unknown elsewhere. Jonathan Otley, the old Lake District geologist and guide, long ago (1820) attributed them to masses of vegetable matter, buoyed up by the gases from the decaying tissues, and this explanation has been generally accepted.

Lakes fulfil a most useful function in regulating the flow of rivers. In America, for instance, the St. Lawrence and the Ohio are strongly contrasted in this respect. The Ohio, which has no lakes, is subject to floods, which rise 50 to 60 feet; while the St. Lawrence, which flows from the great lakes, varies comparatively little.

THE LAKE DISTRICTS

Our principal Lake Districts are the country of the Broads in East Anglia, the Welsh Lake District, and that of Cumberland and Westmoreland.

Charles Kingsley, speaking of the Broads and Fens, truly said: "They have a beauty as of the sea, of boundless expanse and freedom. . . . Overhead the arch of heaven spread, more ample than elsewhere, as over the sea, such sunrises, such sunsets, as can be seen nowhere else within these isles." The Broads are bounded by dense growths of tall water-grasses, bulrushes, reeds, and sedges, interpersed with the spires of the purple loosestrife, great epilobium, willow-herb, hemp-agrimony, and other flowers, a dreamy paradise of insects, fish, birds, and other

animals, surrounded by breezy stretches of heath and gorse, and bounded in the distance, where any distance can be seen, by wood-girt hills.

Very different, but no less beautiful, are the lakes and tarns of Wales and of the North.

Few parts of the world, if any, surpass the loveliness of the Welsh and English Lake Districts, and especially, I think, in the volcanic regions. We cannot, of course, compare them with the Coral Islands of the Pacific, and other regions of a totally different character. Scotland may be more stern, Switzerland may be grander, and may impress on us more deeply the irresistible forces of nature. But the small scale of our Lake District is in some ways an advantage. The numerous islands, and the view of the opposite shore, for instance, add greatly to the beauty of the scene. In Scotland it must be admitted that many of the most beautiful parts are separated by long tracts of desolate country. Of Switzerland also to some extent the same remark may be made, and the foreground is somewhat dwarfed by the giant mountains.

In Wales or in the Lake District, after ascending the valleys for a few hundred feet, you might well fancy yourself at an elevation of several thousand. The mountains are, moreover, high enough to be softened and coloured by distance, and the frequent showers add greatly to the aerial effects.

The mountains are, of course, diminutive as compared with the giants of the Alps and the Himalayas, but the beauty of a mountain depends mainly on form, and on relation to its surroundings;

and a mountain of 3000 feet, if not dwarfed by higher peaks, has a grandeur of its own.

This is still more true of lakes. Their beauty is certainly not to be measured by their size. If, indeed, they are too wide, the shores cannot be well seen at the same time, and a distant shore limits the view without adding to the beauty. Even among the English lakes Grasmere and Rydal need fear no comparison with Windermere or Ullswater. On the small lakes with shallow edges the tall water-grasses and bulrushes add much to the beauty.

The climate of the Lake District is no doubt moist, but this adds to the luxuriance and beauty of the vegetation. Another great advantage is that the hills are mainly, indeed almost entirely, used for pasture, and the rocky knolls, therefore, have been left in all their natural beauty. If the rain often comes down "heartily," some part of the day at any rate is generally fine.

The trees are magnificent; they thrive wonderfully on the deep glacial drift.

While heather is the characteristic plant of the Scotch hills, bracken (fern) is most abundant in the Lake District. Heather is perhaps the more beautiful just when it is in flower, but taking the whole year round it may be doubtful whether fern does not add richer tints to the hillsides. The great changes in colour at different seasons are principally due to the bracken.

The damp climate also suits the mosses and lichens, which grow luxuriantly, and add much to the

richness of the colouring. After rain the leaves and grass become a brighter green, and "every sunburnt rock glows into an agate."

In many mountain countries the streams are turbid with glacier mud. Ours, on the contrary, are clear as crystal.

The beauty of our Lake District is, moreover, by no means confined to the summer months. In winter the oak coppices retain their russet leaves, the silvery stems and puce-coloured twigs of the birch, the rich green leaves and red berries of the holly, the stems of the larger trees often clothed with ivy, the tracery of the smaller branches, the brown bracken, grey and purple rocks, and last not least the silvery snow, all make a picture rich in colour and beautiful in outline; so that our Lake District, if others may be more sublime, more grand, or more striking, is certainly one of the loveliest in the whole of our beautiful world.

CHAPTER XIII

ON THE INFLUENCE OF THE ROCKS UPON SCENERY

THE character of scenery depends mainly on denudation and weathering, modified by the climate, the character, the chemical nature, the height, and the angle of inclination of the rocks.

The total thickness of the sedimentary rocks has been estimated roughly at 200,000 feet; and as almost the whole of this was deposited in seas or lakes, and was derived from former continents, we see how enormous the amount of denudation must have been, especially if we bear in mind that much rock has been washed down and deposited, then raised and afterwards washed down again—some of it, moreover, several times.

The principal forces which have disintegrated rocks are—(1) water; (2) changes of temperature; (3) chemical action; (4) vegetation.

There are few rocks which are not more or less alterable by, or soluble in, water. It soaks in and filters through innumerable crevices, dissolving some substances, especially when it is charged with carbonic acid, and leaving others. It also acts mechanically; for as it expands when freezing, it splits up even

the toughest rocks, if only there are any crevices into which it can enter. In a dry climate, therefore, the slopes will generally be steeper than in a more rainy region. Even in the absence of water, changes of temperature have a considerable effect, owing to the fractures which they produce by the successive contractions and expansions to which they give rise.

These, however, though the principal, are by no means the only factors in denudation. The roots of plants, for instance, have a considerable effect, insinuating themselves into the smallest crevices and, as they expand with growth, enlarging them by degrees. Yet, on the whole, the action of vegetation is conservative. It absorbs much of the rainfall, and the formation of torrents is thus greatly checked. Some of the French Alpine districts and much of Northern Africa have suffered terribly, and in fact been reduced almost to deserts, by the reckless destruction of forests.

We have in England, speaking broadly, four types of scenery: firstly, that of the older rocks, forming the mountains of the north and the west; secondly, the lowlands of Central England, due to the New Red Sandstone, the Lias, Oolite, etc.; thirdly, the Chalk Downs; and fourthly, the alluvial flats at the mouths of our rivers.

Formations that are thick, uniform, and wide-spreading generally give rise to a more or less undulating country; while those which are thinner and more varied tend to cause a broken outline.[1]

[1] Whitaker, "Geology of London," *Mem. Geol. Surv.*

Any marked rise in the ground, or change of feature, as a rule indicates a change of formation. Again, such changes are often indicated by angles in roads.

Different kinds of rocks are very differently affected by atmospheric influences.

Silicious rocks are liable to disintegration by weather; but, on the other hand, the separate grains of sand or quartz are not only insoluble, but offer great resistance to mechanical action. Water, especially if charged with carbonic acid, can dissolve some silica, but the quantity is insignificant.

Calcareous rocks are much more readily attacked. They often contain some alumina and silicious nodules, which remain as a reddish clay with flints after the calcareous matter has been removed.

Argillaceous rocks cannot be dissolved, but they are in many cases readily reduced to fine particles and then easily removed. They generally contain some calcareous material, and when this is washed away pores and hollows are left which let in moisture. Even when compressed into slates they often yield to the influence of moisture, and if sufficiently saturated sink into the form of mud. They are also very liable to slip when saturated by rain. Hence railway cuttings in clay have very sloping sides, and clay districts are damp and flat.

Along the sides of valleys calcareous rocks often present steep, even vertical, faces (see Fig. 134, p. 325, Valley of Bienne). Sandstones and Granite are generally less bold, and marly beds assume still more

gentle slopes The behaviour of argillaceous beds is more dependent on circumstances; if they are fairly dry they bear themselves well, but if they become wet they are very perishable.

Gravelly districts present picturesque hills.

The varied character of the strata round London gives the beautiful and diversified character of the district, and the numerous commons are due to the sands and gravelly strata.

So varied are the conditions, that every mountain, even if the top only is visible, has a character and individuality of its own.

Not one of these innumerable forms is accidental. Every one of them has its cause and explanation, though we may not always know what it is.

The same configuration will of course look very different from different points of view. What seems like a sharp point is often the end of a ridge. The harder rocks, as in the so-called "Edges" (Wenlock Edge, Alderley Edge, etc.), often slope up gently to the summit, and then drop away suddenly in a steep cliff, frequently broken into a succession of steps. They give therefore what has been happily called by Leslie Stephen a desk-like form (Fig. 188), presenting broad, gently inclining plateaux, ending suddenly in a steep, sometimes almost perpendicular, precipice, which towers like a wall over the valley.

We might at first be disposed to anticipate that from their hardness and toughness the crystalline rocks would be less liable to denudation than the calcareous. And in a sense this is true. In con-

sequence, however, of these very qualities the drainage in crystalline districts is mainly superficial, while in calcareous regions much of the rainfall sinks into the ground. Thus the Chalk Uplands, though cut into along the margins by deep combes, and presenting many shallow dry valleys, are seldom intersected by rivers, and almost all our railway lines leaving London have been compelled to tunnel through the chalk. So also in Switzerland the calcareous strata form long continuous ridges, of which the great wall or the Bernese Oberland is a marvellous example.

Another reason for the extremely bold character of the calcareous mountains is that such strata are very inflexible, and where argillaceous rocks would gradually bend, calcareous rocks break away, and thus give precipitous cliffs.

It was at one time supposed that each kind of rock gave its own special mountain form. This was the view, for instance, even of such excellent observers as Von Buch and Humboldt. It would, however, be quite a mistake to suppose that particular contours always indicate the same kind of rock. On the contrary, we find the same forms in different rocks, and different forms in the same description of rock. They depend greatly on the hardness of the rock, and on the angle at which it stands. Thus tower-like forms occur in Granite, Amphibolite, Sandstone, Conglomerates, Dolomite, etc. The desk-like form which is so frequent in calcareous strata (see for instance Fig. 188, on the right-hand side) occurs also in some districts of

Gneiss or of gravel deposits, as for instance at the Rigi. On the other hand, the same rock may give a very different landscape. Thus Granite often assumes rounded outlines, but often also gives wild ridges of teeth and needles.

Gneiss summits with gently inclined beds are less steep and less pointed, while calcareous rocks if hard and steeply inclined assume not only wild but grand outlines.

On the other hand, in any given district similar geological structure will generally give similar scenery.

Steeply inclined strata produce, as a rule, bold outlines, while those which are more horizontal give a tamer scenery.

In districts of the softer rocks we naturally miss the bold, steep precipices, the jagged ridges and noble peaks, and must content ourselves with smiling landscapes and gentle undulations.

Another reason which affects the landscape in districts of sedimentary and crystalline rocks is that the former crumble away more rapidly, and thus more quickly lose the rounded surfaces due to ice action. Thus, as we ascend the valley of the Reuss, where we leave the softer strata and enter the district of Gneiss, we also commence a scenery of knolls rounded by ice.

In calcareous districts "weather terraces" form a special feature (Fig. 134, p. 325). They are due to a succession of rocks of different hardness and toughness, so that some strata weather back more quickly

and take a gentler slope than others. Crystalline rocks are generally more homogeneous, weather more evenly, consequently present more regular and continuous slopes. Weather terraces are particularly conspicuous in certain lights, and especially in winter when there is snow on the gentler slopes. Even in summer, however, the contrast of vegetation is often striking, some lines being marked out by luxuriant grass or bushes, while others are comparatively bare. On Granite or Gneiss a good mountaineer can go almost anywhere, while in

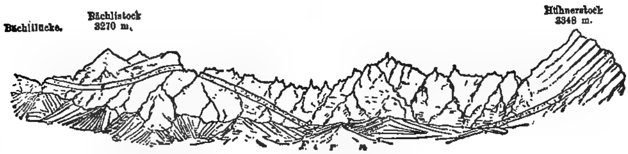


Fig. 188.—Ridge of the Gauli. Profile of the ridge from the Bächlistock to the Hühnerstock, showing the peaks of the Granite rock and the desk-like slope of the calcareous strata forming the Hühnerstock.

mountains of sedimentary strata he is stopped from time to time by an impassable precipice.

On the whole, when seen from a distance, the forms of the sedimentary mountains are more marked, more broken, and, so to say, more individualised.

Crystalline regions present very different forms. The "desks," terraces, pinnacles, and cornices disappear, and we have noble pyramids. The ridges, moreover, are more jagged and serrated. Fig. 188 shows the contrast of a jagged crystalline ridge and the desk-like form of the calcareous strata on the right. The summit of the Jungfrau also shows well

the contrast between the Gneiss at the top and the calcareous rock below.

In the splendid panorama seen from Bern the crystalline mountain-peaks (Finsteraarhorn and Schreckhorn, Breithorn, Tschingelhorn, etc.) can readily be distinguished from the calcareous mountains (Blümlisalp, Doldenhorn, Aletsch, etc.).

Fig. 189.—Volcanic Rock, Ambleside.

The differences of hardness and great variations of texture, even within a small area, give the volcanic districts a peculiar rough and knobby appearance (Fig. 189), with craggy outlines, forming a marked contrast with the smooth and flowing outlines of the sedimentary series. See, for instance, Fig. 96 and Fig. 189, compared with Fig. 42 or 101.

Volcanic ashes, when they first fall, are loose and

incoherent; but water percolates freely through them, and they are often converted by chemical change and pressure into rocks of extreme hardness. They are also peculiarly rough from the differences in size, texture, and chemical composition of the fragments they contain. This gives them a peculiar appearance (Fig. 189), and it is this hardness and roughness which renders the volcanic rocks of the Lake District the happy hunting-ground of English rock-climbers.

Granite is regarded by poets as peculiarly resisting, and it is described as

> Stern, unyielding might,
> Enduring still through day and night
> Rude tempest shock and withering blight.

As a matter of fact, however, granites, as a rule, are very susceptible of disintegration. Granite mountains tend to gentle, rounded, and massive forms.

Rain, and especially water charged with carbonic acid, acts on Granite profoundly. In many quarries where the rock looks solid enough it will be found to be disintegrated to a considerable depth; in Cornwall often to 30 or 40 feet, in China it is said even to 200 feet. This is due to the felspar; the alkaline salts of soda and potash being decomposed by the carbonic acid, leaving the silicate of aluminium, the mica, and the quartz. It seems at first inconsistent with this that Granite ridges are often peculiarly jagged; but in such cases the Granite is steeply inclined, and the debris are removed as they form.

In other cases Granite shows a tendency to weather in convex, but somewhat flat, shells, as shown in Fig. 27, p. 119, representing the Granite coast of Cornwall at the Logan Rock, and to split vertically in two or often three different directions; it is divided, moreover, into horizontal layers at more or less regular intervals, thus forming rhomboidal blocks or pillars. Granite possessing this structure often assumes very bold, wild forms.

Fig. 190, representing the so-called Cheesewring, near Liskeard, is a characteristic example of weathered Granite, and gives a faint idea of the amount of denudation that has taken place.

In Granite districts "the quiet streams, springs, and lakes are always of exquisite clearness, and the sea which washes a Granite coast is as unsullied as a flawless emerald. It is remarkable to what an extent this intense purity in the country seems to influence the character of its inhabitants. As far as I remember, the inhabitants of Granite countries have always a force and healthiness of character, more or less abated or modified, of course, according to the other circumstances of their life, but still definitely belonging to them, as distinguished from the inhabitants of the less pure districts of the hills."[1]

Slate rocks are often characterised by "jagged teeth like the edges of knives eaten away by vinegar, projecting through the half-dislodged mass from the inner rock, keen enough to cut the hand or foot that rests on them, yet crumbling as they

[1] Ruskin.

Fig. 190.—The Cheesewring, near Liskeard. Illustration of Weathered Granite.

wound, and soon sinking again into the smooth, slippery, glutinous heap, looking like a beach of black scales of dead fish, cast ashore from a poisonous sea."[1]

The Skiddaw slates are generally of very uniform texture, fine-grained, soft, and split down the planes of secondary, almost as easily as along the true, cleavage. The consequence is that "the mountains of this slate," as John Phillips remarked, "have smoother contours, more uniform slopes, and a more verdant surface than those of the Borrowdale series" (green slates and porphyries). "Hence the smooth slopes of Skiddaw and the rude crags of Scawfell."[2]

The Old Red Sandstone is generally hilly and undulating. It often gives rise to a poor, stony, and pale red soil, frequently forming wet and boggy moorland. This is particularly the case on the Mendip Hills, where the sterile character is exaggerated by elevation and exposure.[3]

In places, however, it is fertile and largely devoted to pasture; many orchards are situated upon it, and a few hop-gardens. The Cornstone, which belongs to this period, forms much of the richest land in Herefordshire.

Indeed, the famous orchards of Devonshire, Gloucestershire, Herefordshire, and Worcestershire lie mainly on the red soil of the New and Old Red Sandstone.

Carboniferous Limestone presents smooth outlines,

[1] *Modern Painters*, vol. iv.
[2] Woodward, *Geol. of England and Wales.*
[3] *Ibid.*, *Mem. Geol. Surv.*, East Somerset.

Fig. 191.—Middleton Dale, near Eyam, Derbyshire.

well-rounded grassy slopes, and deep narrow valleys with nearly perpendicular sides (Fig. 191), often clothed with shrubs and ivy, the rich green of which contrasts well with the white rock.

But though the Limestone is in one sense uniform, it presents minor variations which divide it into beds or strata of different texture and hardness. There were no doubt also from time to time pauses in the deposition, during which the surface of the deposit became slightly consolidated and hardened, thus forming what are known as bedding planes. The Limestone is also traversed by vertical and horizontal lines which divide it into cubical masses, and thus give rise to the characteristic scenery of such districts.

This rock, indeed, gives rise to some of our most picturesque scenery. The valleys are bold and beautiful. "The fair bright islands of Killarney," says Sedgwick, "the Clefts of Cheddar and St. Vincent's Rocks, the delicious valleys of the Wye and the High Peak, and (to come nearer the Lake Country) the sublime gorge of Gordale, the fine grey precipices at the foot of Ingleborough, the caverns of Chapel-le-Dale and Clapham, the rocks of Kirkby Lonsdale Bridge, and the great white terrace of Whitbarrow—all belong to the features of this Limestone."

The Carboniferous Limestone, says Symonds, is beloved by the geologist for its picturesque scenery, its caves with their stores of old bones, and the number and variety of its fossils; by the botanist for

the rare and beautiful plants nourished in its fissures and on its slopes; by the archæologist for its cromlechs, old camps, and ancient dykes; and by the historian for its memories of many a hard battle and many a struggle for independence fought out to the death among its ravines and dingles.[1]

Fig. 192.—Bare surface of Carboniferous Limestone, near Shap, showing "grikes" or widened joints.

In calcareous districts the surface is sometimes quite bare and intersected by furrows, attaining a depth of several, sometimes even as much as 30 feet. Such districts are known on the Continent as "lapiées" or "karren."

The hollows often contain a certain quantity of soil, and grass, ferns, etc., take advantage of the shelter.

The scenery of Sandstone districts is very different.

[1] Symonds, *Records of the Rocks*.

The Millstone Grit forms wild wet moorlands, marked by long lines of terraced or steeply scarped hills, which contrast strongly with the undulating plains of the Trias, the more varied outlines of the Coal-measures, and the rounded hills or deep dales of the Carboniferous Limestone. We continually see the same form of outline, consisting of a gently rising surface of moorland, broken off along a line of sharp cliff. These escarpments are known as Edges—Axe Edge near Buxton, Bamford Edge, Black Edge, etc. By these physical features the position and arrangement of the strata are marked out with wonderful clearness, the summits of the ridges and escarpments being composed of grit or sandstone, the flanks of the hills and the valleys of shale; and as the steep face of the escarpment always tends to run in the line of strike, and looks in the direction opposite the dip, the observer can often from some commanding point trace out the geological structure of the country by aid of its surface configuration alone.[1]

So also in Wales, as soon as we leave the sandy and silicious beds of the Lower Silurian and come to the "mudstones" of the Upper Silurian, we pass from wild heaths and poor moorlands to luxuriant woods and rich arable lands.[2]

The Trias, says Phillips, "is marked everywhere by comparatively gentle features, easily swelling undulations, relieved here and there by picturesque

[1] Hull and Green, *Quart. Jour. Geol. Soc.* vol. xx. 1864.
[2] Murchison, *Silurian System.*

cliffs of sandstone over a pleasant river. In no part of the island does the sandstone of this series make hills more than 1000 feet above the sea; one of the more conspicuous being the ridge on which Nottingham Castle stands. The marly parts of the New Red are generally fertile, the sandy and pebbly parts less so, or even barren."

The "red ground" of the Trias forms the rich meadow and pasture land of Cheshire. The marls are well suited for orchards. Here also is situated the cultivation of the teasel, the heads of which are used in the cloth-mills.

Sherwood Forest, as Aveline has suggested, is probably due to the poor sandy and gravelly soil of Triassic age, the greater part of which still remains as woodland or common.

A considerable part of the pastures and meadowland of Central England is due to the Lias Clay, the Limestone beds of the same period being generally arable. The Lower and Middle Lias also often forms fruit-growing districts, as in the vale of Marshwood in Devonshire, at Glastonbury, as well as near Evesham and Cheltenham.

"The Inferior Oolite frequently forms tabulated spurs bounded by abrupt banks, which are planted with beech-trees and pines; of such there are good examples in Slaughterford Valley."[1]

Professor Sedgwick[2] has observed that the large area of fen-land occupying the Bedford Level and a

[1] *Mem. Geol. Survey*, "Geol. of Parts of Wiltshire and Gloucestershire."
[2] Woodward, *Geol. of England and Wales.*

considerable portion of Lincolnshire rests on a deposit of clay of great but unknown thickness. The lower portion of this deposit belongs to the Oxford Clay, and the higher part to the Kimmeridge Clay.

The Weald Clay, which forms a belt round the Hastings Beds, is of a very different character. The soil is very stiff, and in old times the roads were almost impracticable in wet weather. The general flatness added, moreover, to the difficulty of drainage. Indeed, in the Weald area generally the roads were execrable.

The Romans seem to have only made one road across the Weald. To the east there is supposed to have been an older or British track, and these are said to have been the only two routes across the Weald for several hundred years after Roman times. Knowle, near Sevenoaks, is said to have been given by Queen Elizabeth to the Sackvilles "on account of the foul ways in Sussex," which made it impossible for them to reach Buckhurst, their Sussex home, in winter. In many districts carriages were not generally, because they hardly could be, used. Pack-horses were employed till quite recently; and as lately as 1818 Bishop Buckner advised a clergyman, whom he had ordained as curate of Waldron, to go there at once, as when the winter once set in he would find it impossible.

Arthur Young, in his tour through England (1771), speaking of the Sussex Weald, tells us that "Here I had a sight, which indeed I never saw in any other part of England, namely, that going to

church in a village not far from Lewes, I saw an ancient lady of very good quality drawn to church in her coach with six oxen: nor was it done but out of mere necessity, the way being so stiff and deep that no horses could go in it."

The Lower Greensand strata present considerable diversity. In parts they are poor, and present considerable areas of waste. Elsewhere, as for instance near Maidstone, they are very fertile, and much sought after for orchards and hop-gardens.

Near Ightham the Lower Greensand forms an extremely hard and peculiar rock, which has resisted denudation, forming high ground which was selected by the Romans as the site of a camp.

The Gault occupies only a narrow belt of country between the Upper and Lower Greensand. The largest area of Gault, and also the district where it attains its greatest height, is that of Alder Holt or wood. The name, however, is unfortunate, as the oak, not the alder, is the predominant tree.

A large proportion of the Gault is pasture-land, and lies low, that in West Kent and Surrey forming what is known as "the winding valley of Holmesdale."

The Upper Greensand, so far as the Weald is concerned, also forms a narrow strip lying immediately under the Chalk escarpment. Near Godstone, however, it runs out from the escarpment, and forms a well-marked terrace, with a steep front; and this character it retains throughout the greater part of its range in Hampshire and Sussex. It is perhaps best

seen in the neighbourhood of Selborne, where the steep wooded slopes are known as "hangers."

The Upper Greensand is perhaps, on the whole, the most fertile part of the Weald. It is generally arable; woods being almost confined to the steep slopes, and comparatively little is in pasture. There is hardly any waste land. Hops are the characteristic crop of the Greensand in Kent, West Surrey, East Sussex, and Hampshire.

The structure of the Weald exercised a material influence over the arrangement of the Kentish railways. The North Kent line, of course, kept to the north of the North Downs. To avoid expense as far as possible the South-Eastern and the London and Brighton ran a joint line up Smitham Bottom, and by the Merstham tunnel to Reigate. There the South-Eastern diverged almost at a right angle, and ran in a straight line to Ashford. Thus, so far as the Folkestone and Dover traffic was concerned, the line went much out of its way towards the west. Then came the London, Chatham, and Dover line. They availed themselves of the gap in the Chalk escarpment formed by the Medway. This, however, also involved a considerable detour, and at length the present line was constructed, involving three long tunnels, one through the Tertiary escarpment at Chiselhurst, one through the Chalk escarpment at Madamscourt Hill before reaching Sevenoaks, and another through the Greensand ridge immediately after leaving Sevenoaks. Even now, however, the line to Dover is far from being direct.

The Chalk presents high hills, fine escarpments, and steep slopes, characterised by soft and rounded outlines.

The scenery of the Chalk is very characteristic. William Smith, "the father of English Geology," speaking in 1794 of the view from the top of York Minster, said, "From the top of York Minster I could see that the Wolds contained Chalk by their contour."

But the Chalk itself presents certain differences. "The Upper Chalk (in Wiltshire) is hard, and contains innumerable layers of flints. These, being washed out and left exposed where the Chalk has been decomposed and carried away in solution, thickly cover the ground not only of the higher hills occupied by the hard Chalk, but they have also been drifted down and spread over the lower soft Chalk.

"The unequal denudation of the hard and soft Chalk forms a striking feature in this part of the country, especially when viewed from the west and north-west. The hard Chalk rising abruptly out of the high and broad plateau of the soft Chalk, the bare grassy sides and tops of the former contrast strongly with the cultivated plains of the latter. And while the plateau of the Lower Chalk rises and falls in gentle undulations, interspersed with small streams, the Upper Chalk is cut up into numerous ridges and valleys, and is nearly destitute of water."[1]

The Bagshot Sands, being poor and barren, have

[1] Aveline, *Mem. Geol. Surv.*, "Geol. of Parts of Wiltshire and Gloucester."

often been left uncultivated, and hence many of the commons round London. Being, however, sandy and dry, they are very healthy. They form, therefore, as for instance at Aldershot, excellent ground for military camps.

Very much the same might be said of the Upper Eocene beds which occupy a large part of the New Forest; and though William the Conqueror is often said to have depopulated the region, we may doubt whether there ever were very many inhabitants.

The open commons of Surrey, and the tracts of gorse and heath, of broom and pine, in our Home Counties and in East Anglia, are due to the Tertiary sands and gravels.

"The sites of the Tertiary outliers are well marked, by being either covered with wood or else by the ground being under cultivation, thus forming a strong contrast to the open downs of the higher Chalk formation."[1]

Glaciated regions present two totally distinct types of scenery: a central or upper of bare barren rock with rounded outlines (Figs. 5-7, pp. 50, 51, 53), and a peripheral ring of debris in scattered heaps and long mounds.

These morainic deposits give a peculiar character to the scenery: the country is diversified and irregular, thrown into confused heaps and depressions, which, as the lower or ground moraine is very impervious, often contain small lakes. Such districts are well watered, and the rich network of rivers often

[1] Aveline, *Mem. Geol. Surv.*, "Geol. of Parts of Wiltshire and Gloucester."

take very devious courses. Desor has happily characterised such a district as "un paysage morainique."

The chalky Boulder-clay of Norfolk and Suffolk presents a bald surface of heavy land which forms one of the principal wheat-growing districts, if not the principal, in England.

Clay is not generally regarded as a healthy soil, but Dr. Buckland is said to have remarked that he "could always tell when he was on Boulder-clay by the rosy cheeks of the lasses."[1]

The scenery is again affected very much in consequence of the influence of different strata on streams and springs. For instance, in a country of hard, impervious rock we have numerous little runnels which gradually unite into larger and larger streams. On the contrary, in a calcareous district, especially if fissured, we find, as for instance in the Downs and elsewhere, large districts with very few streams, and here and there copious springs, where the water is brought to the surface by some more impervious stratum. A glance at any geological map will show that the districts occupied by Chalk are especially waterless.

Clay districts are generally wet, but this is not an invariable rule. The Upper Ludlow rocks contain beds of clay, but they are so full of joints and fissures that the rain is rapidly carried off, and the ground consequently is dry.[2] Hence we see that we have to consider not merely the chemical com-

[1] *Proc. Geol. Ass.* vol. ix. 1885.
[2] Murchison, *The Silurian System.*

position, but also the presence of faults, fissures, etc.

Speaking generally, arable land prevails in the east, and pastures in the west, the moister air and more equable temperature being favourable to grass, while a drier climate is more suitable for wheat. In the eastern counties the proportions of corn and pasture depend mainly on soil, the sands and gravels producing a wheat country, while the clays and calcareous districts favour pasture.[1] In this respect, however, most maps are rather deceptive. Kent, for instance, is generally represented, and correctly enough, as having a large area of Chalk. It is, however, so much covered with surface deposits that there is comparatively little down, most of it being either arable or woodland. So also in the low country north of the Thames, and the lower Severn valley, the thick covering of drift affects the agriculture and makes our ordinary geological maps almost useless for agricultural purposes.

In Northern England the limit of cultivation is reached at a height of about 1000 feet, above this being rock moorland and hill pasture.[2]

On the high ground part of the flora is of Scandinavian origin. Among such species may be mentioned *Cornus suecica*, *Trientalis europæa*, *Potentilla alpestris*, *Sedum villosum*, and *Salix herbacea*, which occurs on Ingleborough.

Limestone and Chalk support a short, sweet, green

[1] Topley, "Agriculture of England and Wales," *Jour. Roy. Agric. Soc.* vol. vii. 1871.

[2] *Ibid.*

turf; slopes of Shale give a stunted growth of wiry grasses and bluish sedge; while Gritstone "Edges" are clothed with red or brown heaths.

It is remarkable how many of our common trees have been brought by man and are of recent, some of very recent, introduction; for instance, the common Elm, Spruce Fir, Larch, Lime, Horse-chestnut, Plane, Lombardy Poplar Acacia, etc.

CHAPTER XIV

DOWNS, WOLDS, FENS, MOORS, AND COMMONS

And forth into the fields I went,
And Nature's living motion lent
The pulse of hope to discontent.
. . . .
I wonder'd, while I paced along:
The woods were fill'd so full with song,
There seem'd no room for sense of wrong.

TENNYSON.

THE DOWNS

_F there is one geological formation which more than any other is characteristic of England, it certainly is the Chalk. The Chalk cliffs protect our shores, and have given a name to our island. The Chalk Downs occupy the heart of England. Being, as a rule, higher than the surrounding country, the air is cool and pure, crisp and sweet: being generally in grass, they are silent and peaceful, giving a delightful sensation of solitude and repose, heightened rather than interfered with by the occasional tinkle of a sheep-bell or the cry of a plover.

The Downs present a series of beautifully smooth, swelling curves, perhaps the most perfect specimens

of graceful contour, and are covered with short, sweet, close turf.

Turf is peculiarly English, and no turf is more delightful than that of our Downs—delightful to ride on, to sit on, or to walk on. It indeed feels so springy under our feet that walking on it seems scarcely an exertion; one could almost fancy that the Downs themselves were still rising, even higher, into the air.

The herbage of the Downs is close rather than short,—hillocks of sweet thyme, tufts of golden potentilla, of milkwort—blue, pink, and white—of sweet grass and harebells; the curiously named "squinancy wort," with its small but fragrant blossoms; here and there pink with heather, or golden with furze or broom; while over all is the fresh air and sunshine, sweet scents, and the hum of bees. And if the Downs seem full of life and sunshine, their broad shoulders are types of kindly strength, so that they give an impression of power and antiquity; while every now and then we come across a tumulus, or a group of great grey stones, the burial-place of some ancient hero, or a sacred temple of our pagan forefathers.

On the Downs, indeed, things change slowly, and in parts of Sussex the strong slow oxen still draw the waggons laden with warm hay or golden wheat-sheaves, or drag the wooden plough along the slopes of the Downs, just as they did a thousand years ago. I love the open Down most, but without hedges England would not be England. Hedges are everywhere full of beauty and interest, and nowhere more

so than at the foot of the Downs, where they are in great part composed of wild guelder-roses and rich dark yews, decked with festoons of traveller's-joy, the wild bryonia, and garlands of wild-roses covered with thousands of white or delicate pink flowers, each with a centre of gold.

The drainage of the Downs is almost entirely subterranean. They are indeed intersected by many branching valleys, which have all the appearance of water-courses, but are now dry. Their origin has been already referred to (see ante, p. 336). The rain in fact sinks into the ground and gushes out at the foot of the Downs in clear sparkling streams—rain from heaven purified still further by being filtered through a thousand feet of Chalk, fringed with purple loosestrife and willow-herb, starred with white water-ranunculus or rich water-cress; while every now and then a brown water-rat rustles in the grass at the edge, and splashes into the water, or a pink speckled trout glides out of sight.

One writer on scenery (Gilpin), indeed, who described this country a hundred years ago, condemned the Downs as "entirely destitute of ornament," and considered that "Chalk spoils any landscape."

Gilbert White, however, who was certainly a better judge, in Letter LVII. was of a different opinion: "Though I have now travelled the Sussex Downs upwards of thirty years, yet I still investigate that chain of majestic mountains with fresh admiration year by year, and I think I see new beauties every time I traverse it. . . . For my own part, I think

there is something peculiarly sweet and amusing in the shapely figured aspect of Chalk hills, in preference to those of stone, which are rugged, broken, abrupt, and shapeless."

The Chalk dips gently under the Tertiaries of the London (Fig. 21) and Hampshire basins; but where it terminates and the other rocks crop out, it forms as a rule a well-marked escarpment. In Norfolk and Cambridgeshire, however, it is often a long gentle slope; in some cases because the whole tract east of the Fens was once covered by glacial drift, during the deposition of which the chief prominences were smoothed away; in others because the glacial drift is banked up against it.

The Wolds differ greatly from the Downs, though the Chalk in the two cases is almost identical in composition. The soil of the Downs, however, is loamy, that of the Wolds sandy; and the sand is mainly quartz, not flint. Hence, while the Downs are clothed with short, sweet turf, the Wolds grow naturally only wiry grass, gorse, and moss. The result has been that while the Downs have been to a great extent left as natural pasture, the Wolds are of very little value unless they are manured and cultivated.

We find in East Anglia, besides the Chalk, four well-marked districts—

1. Gravels, Sands, and Heaths.
2. Boulder-clay.
3. The Broads.
4. The Fens.

The Gravels and Sands may be divided into—

1 Marine gravels.

2. Plateau gravels.

3. Gravels of the existing rivers.

The marine gravel skirts the Fenland and passes everywhere under the peat and silt.

The plateau gravels are of fresh-water origin. They form sheets, occupying the higher ground, but have no clear relation to the existing rivers.

The later gravel is that which has been, and is being, brought down by the present rivers. The two latter gravels both contain palæolithic flint implements. Skertchly even considered that he had found similar implements in gravel underlying the Boulder-clay.

The gravel is often arranged in terraces. One forms the "backs" of the Colleges at Cambridge, and skirts the western side of the river north of Newnham. From this level there is a marked rise to a higher terrace, through the gardens belonging to King's, Clare, and Trinity.[1]

From Thetford to the Fens is a sandy, barren country, and, as Skertchly says, "one is often reminded of the deserts of Africa rather than of English scenery. Hardly a drop of surface-water is to be found, and for miles there is neither ditch, pond, nor spring. Little cultivation is possible; but the loose sandy soil is occasionally tilled, the rental averaging about three shillings an acre. Rye is the dominant cereal, and fifty years ago was still the

[1] Penning, *Mem. Geol. Surv.*, Cambridge.

staple bread-stuff of the poor. Barley of good quality is grown in places, and lupins have been extensively grown of late years, for sheep-feeding."[1]

The Boulder-clay has been already described (see ante, p. 61). It reaches a thickness in some places of 400 feet, and has been cut through by many of the rivers. It extends southwards to the margin of the Thames valley, and stretches away far to the north.

The present contour lines of East Anglia are post-glacial. The Boulder-clay stretched far and wide over the country, and filled up all the old river-valleys. In some cases these have been more or less completely re-excavated; but in others the rivers have taken new directions and formed fresh channels for themselves, cutting sometimes not only through the Boulder-clay, but even (as for instance the Wensum, between Norwich and Mousehold) 40 to 50 feet into the Chalk below.

The Broads have been briefly described in the chapter on Lakes.

THE FENS

While the fens and plains of East Anglia cannot perhaps vie in picturesqueness with some other parts of the country, they certainly possess a quiet beauty of their own, and deserve Bishop Hall's commendation as "a sweet and civil country."

All England, said Fuller, with pardonable enthusiasm, might "be carved out of Norfolk."

The air is clear and transparent: fogs are rare,

[1] Skertchly, *Mem. Geol. Surv.*, Cambridgeshire and Suffolk.

and the inhabitants enjoy "as sunny skies, as beautiful starlit nights, and as magnificent cloudscapes as any people in England."[1] Speaking of the luxuriance of the Fenland, Cobbett quaintly said that, "everything taken together, here are more good things than man could have the conscience to ask of God."

The Isle of Ely, said William of Malmesbury, is "a Paradise, for that in pleasure and delight it resembles Heaven itself, the very marshes abounding in trees, whose length without knots doth emulate the stars. The plain there is as level as the sea, which with green grass allureth the eye, and so smooth that there is nought to hinder him that runs through it. Neither is there any waste place in it, for in some parts there are apple trees, in others vines, which either spread upon poles, or run along the ground."

The Fenland encloses the Wash, of which it was formerly an extension, while the Wash itself probably will one day become part of Fenland.

There can be no doubt that formerly the Chalk stretched across the mouth of the Wash from Hunstanton to Lincolnshire, with an escarpment to the west overlooking a plain occupied by Kimmeridge Clay and Oxford Clay, with a capping of Boulder-clay. This Chalk ridge gradually became narrower, as for instance the Chalk ridge of the Hogsback near Guildford is becoming now; and it was no doubt intersected by the Witham, the Welland, the Nen, and the Ouse, just as the North and South Downs are cut across by the rivers of Kent, Surrey,

[1] Wheeler, *Fens of South Lincolnshire.*

and Sussex. By the enlargement of the estuaries, and the existence perhaps of a slight synclinal depression,[1] the Chalk was reduced to islands, and finally removed entirely. The area to the south-west of the Chalk consisted of soft clays. These could offer no effective resistance, and the denudation of the land proceeded rapidly, reducing it to a low plain, the future Fenland. The process continued until the waves were stayed by the harder Oolites. Skertchly estimates that the depth of the basin was at one time at least 600 feet, and the condition of the Fen deposits shows that the country has long been debatable land, with numerous oscillations of level. At present the Wash has an average depth of about 5 fathoms, with a deep elongated hollow in the centre, known as the Lynn Well, which ranges from 15 to as much as 26 fathoms.

The Wash, therefore, says Skertchly, is not an estuary, but a bay; it is not the seaward continuation of a river-channel—a breach of the coast from the land side, but an indentation of the land by the sea—a breach of the coast from the sea side.

It is in fact a sea-plain, not a river-plain, and hence its "Fen" character. A river-plain has a certain inclination—slight, it may be, but sufficient to carry off the river water. Every part of the sea-plain is successively raised to the same level; it is therefore a true plain, and hence the difficulty of drainage. Even Cambridge, 35 miles from the sea, has only an elevation of 13½ feet above the mean sea-level.

Formerly the bay was much larger, but from time

[1] A. Irving, *Proc. Geol. Ass.* vol. xv. 1897-98.

immemorial there has been a process of silting up, and three miles of land have been added since the time of the Romans.

The Wash is the remaining part of this great bay, and is becoming gradually shallower; the bottom is mainly sand and shingle. The deposits are not brought down by the rivers, but are thrown up by the sea. They are the debris of the Yorkshire and Lincolnshire coast, and are deposited at the slack of high-water. As soon as the deposit reaches the level of high-water spring-tides, the glasswort (*Salicornia herbacea*), locally but inaccurately termed samphire, begins to grow.

It is then known as Samphire Marsh, and is overflowed at high-water. The "samphire" tends to check the movement of the water, and thus favours the deposit of silt. Gradually other plants establish themselves, the swamp increases in height, becomes ripe for embanking, and is known as Green Marsh. Wheeler gives the height of Samphire Marsh and Green Marsh as respectively 18·54 and 19·86 feet above the Ordnance datum line (mean sea-level). The sea, in fact, once occupied the whole Fenland, but it is now filling up the bay, and thus building itself out, so that it is only a question of time when the whole of the Wash will be rich and fertile land.

The Fenland may be divided into three divisions[1]—

1. The Gravel-land.
2. The Peat-land.
3. The Silt-land.

[1] Skertchly, *Mem. Geol. Surv.*, The Fenland.

These three deposits indicate three different conditions of the surface. When it was at a certain height, the rivers deposited gravel; when it was flooded with fresh water, the peat grew; when the sea burst in, the silt was deposited. These changes took place over and over again.

The Gravel rises to the highest level, but slopes down to, and under, the peat and silt. On it the villages usually stand. It was early enclosed, and the fields are separated by hedges. It is evidently of fresh-water origin, and must not be confused with the marine gravels. Its greatest height is, I believe, at Glasford, where it rises to 56 feet. No remains of man have yet been found in it. Yet it is, in Skertchly's opinion, certainly post-glacial.[1]

The Peat, though it occupies a much larger area, supports no villages.[2] It is characterised by an almost perfectly even surface, as flat as the open sea, without any hedges, and with long straight black roads, which follow the lines of the drains. It attains a maximum thickness of about 20 feet. It has long ceased to grow, except in one or two places, which probably shows that the climate has become drier.

The Silt-land occupies the north and centre of Fenland, forming about one-half of the whole area. The surface is somewhat uneven, which distinguishes it at once from the peat. It is also slightly higher, being on an average 15 feet above the sea-level (Ordnance datum line).

[1] Skertchly, *Mem. Geol. Surv.*, The Fenland.

[2] Except Benwick, where the peat is very thin, so that practically the village stands on gravel.

Even now it lies so low, and is so liable to attack, both by sea and land, by high tides and great floods, that its preservation is a continual struggle and requires constant watchfulness. The floods brought down by the rivers are carried off by an elaborate system of drainage, and the attacks of the sea are warded off by immense banks. Many of these are of great antiquity. Some have been considered to go back to British times, and those supposed to have been constructed by the Romans are no less than 150 miles in length and 10 feet in height. When first erected they were probably not less than 15 feet in height, with a base of about 25 feet. The gravel on the Roman road near Eastrea has become cemented by iron since it was laid down, and has assumed a red colour, which has given rise to a local legend that the Romans cemented it with blood.

Skertchly calculates "that the maximum rate of accretion is not more than 59 feet per annum." If, he says, "we travel in a direct line along the line oi quickest accumulation, we have to pass over 12 miles of silt before we come upon the first traces of surface peat in Deeping Fen. Now, 4 miles of land have been formed in the past 1700 years, and at the same rate it would have taken 5100 years to have silted up 12 miles. Adding the 12 miles inside the banks to the 4 miles outside the banks, we should have 6800 years as the latest possible date of the newest part of the peat in Lincolnshire."[1]

The fauna and flora still afford interesting evidence

[1] Miller and Skertchly, *The Fenland.*

of former marine conditions, by the presence of sea plants and shore birds.

The fauna and flora of the Warrens, near Brandon, for instance, though now so far inland, comprise a number of distinctly marine species, as was first pointed out by Barrett. Thus the ringed dottrel breeds there, and the inference is that the present birds are the descendants of ancestors which originally occupied the locality when it was really a sea-shore.

The Fenland has seen many alternations of land and marine conditions. Of late the tendency has been to increase the land. But a few centuries ago this vast tract was a swamp, abandoned to the rivers Witham, Welland, Glen, Nen, and Ouse. During the summer it was comparatively dry, though with dark morasses and wide shallow pools fringed with sedges, rushes, and flags, reeds, bulrushes, and water-grasses; but during the winter, and indeed at any season after heavy rains, it was an inland sea, full of fish and teeming with wildfowl. The rivers also brought down some silt from the higher ground, and continually blocked up their own channels, so that they often changed their course. The Witham once flowed out at Wainfleet and the Ouse at Wisbech. So long, said Chief Justice Sir Henry Hobart,[1] in 1617, "as the outfall of Wisbeche had its perfect being, the whole river of Ouse had there its perfect outfall, from whence the town seemeth to have taken its denomination, viz., Ouse or Wisbeche."

[1] Quoted by Miller and Skertchly, *The Fenland.*

Even in comparatively recent times the sea has extended far inland: Bicker Haven, for instance, was an arm of the sea extending to the south-eastern extremity of Bicker. It is now completely silted up, but was open water in Roman times, and was enclosed by the Roman bank.

The Fens themselves were much more flooded than is now the case, while Ely, Thorney, Whittlesey, Eastrea, etc, as their names denote, stood up above the general water-level, attaining a height of some 30 feet. They are bosses of Jurassic Clay covered with gravel. They were naturally chosen as sites for towns, and, when the lower ground was mostly under water, formed strongholds, which afford great capabilities for defence.

The Fens were, and to some extent still are, the home of innumerable birds—swans, geese, herons, teal, widgeons, mallards, grebes, coots, godwhits, whimbrels, knots, dottrels, ruffs, and reeves, and many more; but if the Fen birds have retreated or disappeared, it is some consolation that singing birds have taken their place: the lark, the blackbird, and the thrush are common, and the nightingale has recently arrived.[1]

Unpicturesque as the Fens may appear to some, they possess a beauty and mystery of their own. Those who know them, love them; they delight in the long rows of trees, the occasional windmills, the wide expanses which give a sense of space and freedom, the calm sheets of water fringed with tall

[1] Miller and Skertchly, *The Fenland.*

reeds and sedges and grasses, and the beautiful atmospheric effects.

Reason and conscience tell us that it is right and good that the great Fen should have become, instead of a waste and howling wilderness, a garden of the Lord, where

> All the land in flowery squares,
> Beneath a broad and equal blowing wind,
> Smells of the coming summer.

And yet the fancy may linger, without blame, over the shining meres, the golden reed-beds, the countless water-fowl, the strange and gaudy insects, the wild nature, the mystery, the majesty—for mystery and majesty there were—which haunted the deep fens for many a hundred years.

MOORS AND PEAT-MOSSES

Great stretches of country in the North are moorland. It used to be said that a man might walk from Ilkley to Glasgow without ever leaving the heather. If never quite true, it was not, and is not even now, far from the truth. In the South of England moors are rarer, but they occur, as for instance on Dartmoor and Exmoor.

They are not confined to high ground, for the principal plants by which they are characterised—the heathers, moorland grasses, and mosses (*Sphagnum*), range from the sea-level to the summits of our mountains. At low-levels, however, the action of

streams, and more recently of man, has made the soil suitable for other plants.

The plants which we associate most with moors are the heathers, but the sphagnum moss is probably the most important, and one or two special grasses and sedges are very abundant.

The uplands of Northumberland are a variegated patchwork of dark heather and "white ground," clad in coarse grasses or bents (*Festuca*, *Molinia*, and *Nardus*), which lie more or less bleached for seven or eight months in the year. The herbage of the porphyrite hills and the Limestone series is bright green, that of the Silurian rocks duller.[1]

On the high moors the plants have a hard life. The characteristic vegetation of the moors is Northern. The moor mosses, grasses, and rushes, the bilberry, crowberry, and ling, all extend to the Arctic Circle.

They are, however, hardy rather than Arctic plants. For the moors are a district of extremes—extreme drought and soaking bog, intense heat and intense cold.

We associate the moorland, indeed, with damp—and correctly. In many places the soaking moss is very deep. Nevertheless, the moorland plants could not survive unless they were able to resist periods of lengthened drought. A great part of the moor becomes far drier in a hot summer than any ordinary pasture-land.

The soil is not rich; being undrained, it is wet and

[1] Miller, *Mem. Geol. Surv.*, Otterburn, etc.

almost foul. During the short, hot, and dry summer the ground is scorched, baked, and parched; in winter it is frozen, or sodden and covered with snow for months. Thus climate and soil are both unfavourable, and "hardy Norsemen" alone can survive. Such plants as do so—heathers, bilberry, bracken, rushes, sedges, bog-moss, cotton-grass, etc.—are specially adapted to their surroundings; low, so as not to be torn to pieces by the furious winds; protected by a thick and leathery cuticle, often purplish in colour; the spiracles or breathing-pores further protected by more or less felted hairs, the leaves small, narrow, wiry, and in many cases rolled in upon themselves. They are moreover generally perennial, with large deep roots.

This arrangement is generally permanent, but in some cases the leaves have the power of rolling up and unrolling themselves again. The bluish grass, for instance, *Sesleria cærulea*, which covers large tracts of the Limestone hills, can roll up or unroll its leaves in a few minutes, according to the state of the atmosphere.

A great part was once under water. In it grew water-grasses, water-lilies, sphagnums, rushes, sedges, the water-soldier (*Stratiotes*), potamogetons, and many other water-plants. In winter they died down below the surface, but their leaves formed a continually thickening layer of vegetable soil. Then appeared the bog-vacciniums, cranberry, bilberry, heaths, etc., and at length trees—in the first instance alders and willows.

The presence of peat is in many places greatly due to the Boulder-clay (see ante, p. 61), which forms an impermeable floor, and which was deposited in irregular masses, with innumerable hollows, in which the sphagnum loves to grow. This forms a sort of sponge, which teems with microscopic life—minute algæ, desmids, diatoms, amœbæ, infusoria, rotifers, nematoid and other worms. The stems of the sphagnum die below, and go on growing above.

PEAT

Even on slopes, where one might have expected the water to run away, the peat forms a sort of sponge, makes the surface very marshy, and may reach a thickness of several feet, while in valleys or on flat hill-tops it may attain a thickness of 30 or even 50 feet, covered over by a thin living crust. The parish church of Burbage, near Buxton, is built on piles driven 40 feet into peat.

At the edges of lakes it gradually grows over the water, forming a treacherous crust, in which animals are often bogged. After rain the peat-mosses swell up, so that the surface may vary several feet in height.

The slipping of peat-bogs, though only occasional, is not a rare occurrence. The peat-plants grow, and the peat rises, so that at last, after some unusually rainy period, it breaks out, or the whole bed moves slowly downwards in a semi-fluid mass. The rate of movement is not more than one to two miles an hour,

and is described as most interesting to watch. Silent and slow the peat gathers round any projecting object, and unrelenting buries it on the spot.[1]

Living beings generally have time to escape, but houses and even villages are sometimes overwhelmed.

"In 1697 a bog of 40 acres burst at Charleville near Limerick. In 1745 a bog burst in Lancashire, and speedily covered a space 1 mile long and 1½ mile broad. A bog at Crowhill on the moors near Keighley burst in 1824, and coloured the river with a peaty stain as far as the Humber. In December 1886 a bog of 200 acres burst at Rathmore, and the effects were seen 10 miles off. Nine persons perished in one cottage."[2]

Many other instances of mosses overflowing are on record, as the Moss of Solway, in Dumfriesshire, on 16th November 1771, where 800 acres of land were covered with peat to a depth of 3 to 15 feet; at Poulenard, in the County Louth, in Ireland, on 20th December 1793, when the peat covered the ground to a depth of 20 feet; at Kilmaleady, in the King's County, which commenced 26th June 1821, and covered 150 acres of cornfields, etc. A portion of Chat Moss, it is related by Leland, grew to a great height, burst, and was carried away into Glazebrook, and thence into the Mersey, the waters of which were so spoilt by the peat that, according to Camden, great

[1] Watts, "On Recent Slipping Peat in Ireland," *Trans. Manchester Geol. Soc.* vol. xxv. 1897.

[2] Miall, "On a Yorkshire Moor," *Proc. Roy. Inst. of Great Britain*, vol. xv. 1898.

numbers of fish were killed.[1] As draining operations extend, these irruptions will probably become rarer and rarer.

Many of our peat-bogs seem to have been once forests. The mouldering stumps of oak, birch, hazel, willow, mountain-ash, alder, hazel, Scotch pine, and yew are common. Were the trees perhaps smothered and drowned by the growth of the sphagnum? At present, however, even apart from the direct agency of man, the moors are wasting away. The rivers, deepening their channels, are gradually draining the uplands. Furze and bilberry, crowberry and fern, which flourish at the edges of the moors, are gaining on the moss.

COMMONS

In former times the amount of common land was very great. To leave large tracts of country uncultivated was, however, considered wasteful, and many hundred—indeed several thousand—Acts of Parliament have been passed by which the greater part has been enclosed and divided among the commoners. There are, however, still considerable amounts remaining, even, and indeed especially, round London, where the widely spread gravel-beds being, however beautiful, very barren, presented little temptation to the agriculturist. These beds are in some cases marine shingle, in others river gravels, often at a considerable height above the present streams,

[1] De Rance, *Mem. Geol. Surv.*, Lancashire.

and dating back to a time when the rivers ran at a much higher level, before they had excavated their present valleys.

A Surrey or Kentish common is, however, no mere bit of bare, worthless land, sparsely covered with bents and other coarse grasses and weeds, but is set with birches and junipers, broom and gorse, wild-roses and hollies, yews and guelder-roses, clematis and honeysuckle, growing over white, pink, and blue milkwort, blue veronicas, pink heather, and yellow rock-rose; sweet with the fragrance of the furze and roses and the aromatic scent of the pinewoods.

In the hollows are many pools, fringed by reeds and rushes, irises and water-grasses, with green carpets of sphagnum studded with red sundew, and dotted over with the pure white flossy flags of cotton-grass; while on the water repose the beautiful leaves and still more lovely flowers of the lilies, over which hover many butterflies, while brilliant metallic dragon-flies flash and dart about.

CHAPTER XV

LAW, CUSTOM, AND SCENERY

"What winter-garden can compare for them with mine? True, I have but four kinds—Scotch fir, holly, furze, and the heath; and by way of relief to them, only brows of brown fern, sheets of yellow bog-grass, and here and there a leafless birch, whose purple tresses are even more lovely to my eye than those fragrant green ones which she puts on in spring. Well: in painting as in music, what effects are more grand than those produced by the scientific combination, in endless new variety, of a few simple elements? Enough for me is the one purple birch; the bright hollies round its stem sparkling with scarlet beads; the furze-patch, rich with its lacework of interwoven light and shade, tipped here and there with a golden bud; the deep soft heather carpet, which invites you to lie down and dream for hours; and, behind all, the wall of red fir-stems, and the dark fir-roof with its jagged edges a mile long, against the soft grey sky."—Kingsley, *Prose Idylls.*

TRAVELLERS returning from the Continent, or foreigners visiting England, by way of Calais and Dover, can hardly fail to be struck by the beauty of Kent—the garden of England. The woods and meadows and streams, the fields and hedgerows, the orchards and hop-gardens, are a marvellous contrast to the brown tracts of arable land, divided into strips, and bare of trees, through which so much of the line passes from Paris to Boulogne.

No doubt there is much beautiful scenery in France—mountains, rivers, lakes, and forests; but the absence of hedgerows and scattered trees gives the country a bare and bleak appearance. This is partly due to the French laws of inheritance, which involve the division of land between the children of the deceased. On each division, in order to ensure equality as far as possible, the property is divided into strips, which thus tend to become constantly narrower and more numerous, much to the disfigurement of the scenery, and with grave economical disadvantages. Not only do properties become smaller and smaller, but each consists of more or less strips often at considerable distances apart, so that much time is lost in walking from one to another. Our systems of land tenure have their own drawbacks, but they are of a different character, and probably less serious.

I say "systems," because in fact we have several. "Borough English," for instance, is the law under which, in the absence of a will, land descends to the youngest son. This is an archaic custom, found sporadically in many parts of the world. In my *Prehistoric Times* I have collected a number of similar cases. Glanville suggested as the explanation that "because of his younger age, he may least of all the brethren help himself." It arose perhaps rather from the custom that while the elder sons were provided for as they came of age, the youngest son continued to live with the father, and on his death stepped into possession of what remained.

In our own country it marks perhaps the last localities occupied by the pre-Celtic population. The distribution is very curious. It occurs in Canterbury, Rochester, Westerham, and certain manors in several other counties—for instance, in Middlesex, Essex, Surrey, Sussex, Huntingdonshire, Hampshire, Shropshire, Cornwall, and Nottinghamshire. It was formerly the rule in East Nottingham; while in West Nottingham, which was formerly known as Burgh Francoyn, the eldest son inherited.[1]

Another curious tenure is that of what were known as Lammas lands, which belonged to the community from August to February, and were divided between private owners from February to August. Here the origin of the custom probably was to allow each person to take off a crop of hay, after which the community turned out their stock to pasture in the winter months.

The existence of Lammas lands formerly preserved an open space all round Nottingham, and caused it to be surrounded by a detached ring of manufacturing villages at a distance of one or two miles. In 1845, however, a local Act was passed allowing building leases, and the area is now covered with houses.

These tenures, however, were exceptional. At the time of the Conquest most of our English land was either (1) Folkland, *i.e.* that belonging to the Commune; (2) Crownland, that belonging to the Crown; or (3) Bookland, that granted to individuals by "book" or charter.

[1] Elton, *Tenures of Kent*.

When Folkland was brought into cultivation,[1] it was convenient, in order to ensure equality between the different owners, that it should be divided into strips, of which each burgher had one or more.

The result was that the arable lands were divided into long narrow belts. Hence the frequency of pieces of ground known as the "long acre," one of which still retains its ancient name even at the present day in the very heart of London.

The individual shares in these cases were small, and often at some distance apart. This disadvantage continually tended to increase, and was found so inconvenient that the greater part of the Folklands were eventually divided up—many of them latterly by Enclosure Acts, of which there have been no less than four thousand.

But there was another cause which might also have led to the division of land into strips. The Crownland was granted to individuals on condition of military service. This obligation could not well be divided, and consequently lands held by this tenure descended from one person to another—the eldest son.

On the other hand, Bookland, that held of the Church or of individuals, on the basis of a payment of rent or "gavel," was, before the Conquest, on the death of the holder divided in England, as it is still in France, between all the children. Gavel or "gavelkind" did not, therefore, primarily refer to

[1] See Elton, *Tenures of Kent;* Maine, *Village Communities;* Seebohm, *The English Village Community*, etc.

inheritance but to tenure; and as rent could easily be apportioned, such land on the death of the holder was divided between all the sons.

William the Conquerer abolished the custom of gavelkind in England generally. He swore, however, to respect the rights and customs of Kent, and hence in this county those lands which were Bookland at the time of the Conquest were divided between all the sons, while that which was Crownland went to the eldest. This led to great confusion and endless lawsuits. Many landholders held part of their lands by one tenure and part by another, and so great was the inconvenience that many private Acts of Parliament were passed to "disgavel" particular properties. It was long doubtful whether the custom of gavelkind could be overridden by will, but finally it was decided that this could be done, and the result has been that the tenure of land in Kent has gradually more and more approached that of the rest of England. Practically, therefore, the breaking up of landed properties gradually ceased in Kent as elsewhere.

To this sequence of events we owe the existence of the fields and hedges, hedgerow timber, and winding country lanes which are so characteristic of English scenery, and to which the beauty of England is so greatly due.

The French law inevitably tends to immense open tracts of arable land, divided into strips, but not separated by hedges, without hedgerow timber, and with trees only in extensive forests, or

in interminable rows along the sides of straight roads.

It is a curious fact that, speaking generally, the land which was arable at the time of Domesday is now under grass, while that which was under grass is now arable. This is because in ancient times the best land was under tillage, while at present it is most profitable as pasture. In fact, most of our grass land was once under tillage, and of this we have still under our eyes curious evidence.

In many of our midland and northern counties most of the meadows lie in parallel undulations or "rigs." These are generally about a furlong (220 yards) in length, and either one or two poles ($5\frac{1}{2}$ or 11 yards) in breadth. They seldom run straight, but tend to curve towards the left. At each end of the field a bank, locally called a balk, sometimes 3 or 4 feet high, runs at right angles to the rigs. These fields were originally common, and for fairness of division were arranged in strips or rigs, no man being allowed two contiguous rigs.

The team generally consisted of eight oxen. Few peasants, however, possessed a whole team, several generally joining together, and dividing the produce. Hence we often find eight "rigs," one for each ox. Sometimes, however, there are ten instead of eight; one being for the parson's tithe, the other tenth going to the ploughman.

When eight oxen were employed, the goad would not, of course, reach the leaders, which were guided by a man who walked on the near side. On arriving at

the end of each furrow he turned them round; and as it was easier to pull than to push them, this gradually gave the furrow a turn towards the left, thus accounting for the slight curvature. Lastly, while the oxen rested on arriving at the end of the furrow, the ploughman scraped off the earth which had accumulated on the coulter and ploughshare, and the accumulation of these scrapings gradually formed the balk.

These considerations also explain our curious system of land measurement. The acre is the amount which a team of oxen were supposed to plough in a day. It corresponds to the German "morgen" and the French "journée." It was fixed by the ordinance of Edward I. as a furlong in length and four poles in breadth. The furlong, or "furrow-long," is the distance which a team of oxen can plough conveniently without stopping to rest. Oxen, as we know, were driven not with a whip, but with a goad or pole, the most convenient length for which was 16½ feet; and the ancient ploughman also used his "pole" or "perch" as a measure, by placing it at right angles to his first furrow, thus marking off the amount he had to plough.

Hence our "pole" or "perch" of 16½ feet, which at first sight seems a very singular unit to have selected. This width is also convenient both for turning the plough and for sowing. Hence the most convenient unit of land for arable purposes was a furlong in length and a perch or pole in width.

These "rigs" and "balks" thus carry us back to

the old tenures and archaic cultivation of land, and to a period when the fields were not in pasture, but were arable.

It is fascinating thus to trace indications of old customs and modes of life, but it would carry us away from the present subject.

In Chalk districts well-marked terraces may often be seen running along the sides of the hills. These are locally known as "Lynchets," and have a certain geological interest, as they sometimes present a superficial resemblance to parallel terraces, and have indeed actually been described as raised beaches, as, for instance, by Mackintosh. Poulett Scrope has, however, clearly shown[1] that they are really terraces of cultivation; and indeed any one who lives in counties where they occur may see them actually in the process of formation. Wherever a Chalk slope is under arable cultivation the ridge of soil raised by the mould-board of the plough has a tendency through the action of gravity to slip downhill, never upwards. This downward tendency is greatly assisted by the wash of rain on the sloping surface, and the consequence is that the soil travels slowly downwards.

In early times much of this land was held in severalty by different owners or tenants—the same man often holding several detached strips. In such a case each upper cultivator would take care not to allow the soil of his strip to descend to his neighbour's below. He would draw the lower limit of his strip by a reversed furrow, throwing the last ridge of soil

[1] *Geol. Mag.* vol. iii. 1866.

uphill. This process being repeated year after year would gradually give rise to a balk or lynchet, perhaps several feet in height, with a flattened slope above.

Scrope mentions a case in which such a lynchet was formed in his own time. He owned "a steeply sloping field, which was formerly rough grass-land, having a hedge at its base, with the usual bank of earth on the upper side, raised some 5 feet above the level of the surface on the lower side. Along that upper side of the hedge runs a public footpath. I gave leave to my tenant to plough up the grass slope,

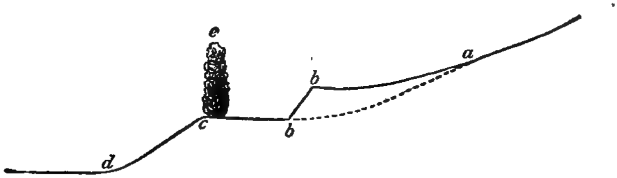


Fig. 193.—Formation of a Lynchet.

which he has now done for about ten years past, and the result has been the formation of a new bank or lynchet as it may be called, from 2 or 3 feet high, above the footpath, which has remained unchanged at its original level. See the illustration [Fig. 193], where the dotted line represents a section of the surface before the plough had broken it up, the firm line that of its present form; *ab* is the newly-formed terrace, *bb* the new balk or lynchet, *cd* the older one, *cb* the footpath, *ce* the hedge. The bank and terrace *abb* are of course composed of soil washed down from the upper slope in the manner above described in the course of ten years' ploughing, and the undisturbed position of the footpath shows

that the fence has had no influence in producing the bank, which can only have been formed by the gradual accumulation of the soil washed down from above in the lowest furrow turned by the plough above the path. The slight ridge of grass that would naturally grow up on the outward edge of this furrow would alone suffice to check the descent of the silt into the path, and cause it to settle above."[1]

In Chalk districts it may be observed that the soil in each cwm is paler at the top, and gets gradually darker downwards. So also the crop will be lighter above and heavier below, because the vegetable mould is thinner above, being constantly washed downwards.

Civilisation, indeed, has immensely modified the face of the country: it has emptied lakes, drained peat-mosses, embanked rivers, and grubbed up forests, turned grass into arable land and arable again into grass, and, last not least, turned country into town. It is astonishing, however, how much remains. Some of our fields, parks, and forests are perhaps even more lovely than they would have been if left to themselves; and at any rate there are great stretches of moorland, heath, and down still untouched, while, above all, along our sea-coast Nature still reigns supreme.

[1] Scrope's "Terraces of the Chalk Downs," *Geol. Mag.* vol. iii. 1866.

CHAPTER XVI

ON LOCAL DIVISIONS

THE names of physical features—of rivers and hills—are mainly Celtic, those of military stations Roman, of villages Saxon and Danish. To the Anglo-Saxons we chiefly owe our parish and county divisions. These have not been determined by chance. In many cases they can be explained by the geology and the configuration of the ground. Topley has pointed out that along the fringe of the Weald the central village of each parish generally stands on the terrace of Upper Greensand at the base of the Chalk escarpment, a site convenient for obtaining water by means of wells. As the villages were planted closely, the parishes are all narrow. They run straight up the escarpment to the crest-line of the Downs, and downwards in a narrow strip across the belt of Gault and the Lower Greensands, down to the valley line of the river.

Thus each parish obtains a portion of wood, of pasture, and of arable land.

ON THE SITES OF TOWNS

A large and increasing part of our country is covered by cities and towns. These are not scattered at random or by hazard over the country, but the sites chosen can in most cases be clearly accounted for.

Many of our cities and towns were ancient fortifications, chosen for facility of defence or as important strategical positions; others are situated at the mouths of rivers, others where rivers meet, others at fords, and some were built round bridges—these, however, much fewer in number, showing that our ancestors did not avail themselves of bridges until a comparatively recent period in our history.

List of certain towns built—

On the sites of ancient fortifications.	At the mouths of rivers.	At fords.	Round bridges.
Bicester	Bournemouth	Ashford	Axbridge
Caister	Cockermouth	Bedford	Bridgewater
Chester	Dartmouth	Bideford	Cambridge
Chesterfield	Exmouth	Bishops Stortford	Kingsbridge
Cirencester	Falmouth	Blandford	Stalbridge
Colchester	Plymouth	Bradford	Tonbridge
Doncaster	Portsmouth	Brentford	Uxbridge
Exeter	Sidmouth	Castleford	Weybridge
Gloucester	Teignmouth	Chelmsford	
Lancaster	Tynemouth	Dartford	
Leicester	Weymouth	Eynsford	
Manchester	Yarmouth	Guildford	
Rochester		Hereford	
Tadcaster		Hertford	
Uttoxeter		Hungerford	
Winchester		Knutsford	
Worcester		Milford	
		Romford	
		Salford	
		Sleaford	
		Stafford	
		Stamford	
		Stratford-on-Avon	
		Thetford	
		Wallingford	

Five of our shires and ten county towns are named from fords, while one city only, Bristol, takes its name from a bridge. Cambridge and Bridgewater are corruptions of earlier names.[1] Uxbridge retains the old name for water, while the Romans were able to impress their name Colonia on the river.[2]

The sites of another series of towns have been determined by the confluence of rivers, where there are often considerable sheets of gravel, so that the inhabitants had the advantage of water, a dry healthy soil, and a situation affording considerable facility of defence by means of one or more earthworks thrown across from one river to the other.

Reading, for instance, is built on the great sheet of gravel at the junction of the Kennet and the Thames, Carlisle at that of the Caldew and the Eden, Tamworth at that of the Anker and the Tame, Oxford of the Thames and the Cherwell, Tewkesbury of the Severn and the (Gloucestershire) Avon, Chepstow of the Severn and the Wye, Monmouth of the Monnow and the Wye, Christchurch of the Avon (Hampshire) and the Stour.

The sites of towns, again, have been often determined by the head of the tide—as Teddington on the Thames, Castleford on the Aire, Tadcaster on the Wharfe, Aldborough on the Ure.[3]

For reasons which have been already mentioned, we have no considerable deltas round our shores, and I need not therefore discuss their influence on the

[1] Taylor, I., *Words and Places.*
[2] Sir Mountstuart Grant Duff, *Diary,* 1889-91.
[3] Phillips, *Yorkshire.*

sites of towns, but may just mention that there is generally an important city when the stream first branches, as, for instance, Cairo on the Nile, Arles on the Rhone, Bangkok on the Menam, etc.; and another on the side of the delta, but some distance from the mouth, where it is accessible by road, as, for instance, Alexandria, Marseilles, etc. Alexandria has retained its excellent harbour for over 2000 years, because it is to windward of the Nile, and the mud and sand brought down by the river are carried away towards the east.

In the Fenland a town was built at the entrance of each river into the Fens, and another at the mouth into the sea—Lincoln and Boston on the Witham; Stamford and Spalding on the Welland; Peterborough and Wisbeach on the Nen;[1] St. Ives and Lynn on the Ouse. Cambridge stands on the Fen border of the Cam, Brandon on that of the Little Ouse, Stoke Ferry of the Wissey, and Steeping on the Steeping river.[2] A similar line along the junction of the uplands with the sea-plain is known in the United States as the "fall line," and is marked there also by a row of cities. Though quite half of the Fenland district is occupied by peat, no town or village occurs upon it.

Another series of towns is built on river-terraces.

Dr. Mill has pointed out that while there are "no villages on the east and west highroad between Chichester and Arundel, or on the railway line, it

[1] Wisbeach was originally at the mouth or "beach" of the Ouse.

[2] Skertchly, *Mem. Geol. Surv.*, Fenland.

is interesting to notice that the disused Chichester and Arundel Canal runs through a chain of villages—Donnington, North Mundham, Merston, Colworth, Lidsey, Barnham, and Ford, each being situated at the point where a north and south road crosses the canal."[1]

In the Arun valley the want of a through road except by water ensured the long isolation of the villages built on the fragments of old river-terraces between the steep Chalk hills on one side and the swampy bottom-lands on the other. But in the Lavant valley the line of communication afforded by the road between Chichester and Midhurst is undoubtedly the cause which gave importance to Cocking and Singleton.

Another series of villages and towns is built on "river-cones" (see ante, p. 310).

The vale of Neath contains a series of such cones or "fans" of gravel, "brought down from the deep drift-laden cwms on either side of the valley, and spread out as deltas on the alluvial flat below. Almost every fan has been utilised as a building site. One of the largest is occupied by Resolven."[2]

Another favourite site of villages is in the sheltered valley heads, well supplied with abundant springs of excellent water.

In the Midland counties the narrow bands where the Keuper Sandstones of the Trias outcrop, rich in springs of good water, relieved by swelling hills or picturesque

[1] *Geog. Journ.* vol. xv. 1900.
[2] Strahan, *Summary of Prog. Geol. Surv. for* 1898.

scarps, and adorned with luxuriant growth of trees, were naturally selected by the ancient inhabitants of the district as the sites of their earliest permanent settlements, and since the dawn of history they have always remained the favourite sites for towns, villages, and mansions. "All the older towns of the district—Warwick, Coventry, Nuneaton, Tamworth, Bromsgrove, Birmingham, Sutton Coldfield, Lichfield, Penkridge, etc.—are built upon the outcrops of the Waterstone formation; and the favourite suburbs of these towns lie along its outcrop—Edgbaston, Erdington, Tettenhall, Stourbridge, Leamington. We find upon it also most of the mansions of the older nobility, such as Whitley, Himley, Hagley, Hewell, Warwick, and Edgbaston."[1]

Again, to the east of Scarborough the villages avoid the great clay valley, and lie along the northern and southern edges, where springs of beautiful water burst out.

Farther to the south the calcareous tract of the Oolites, which form a narrow belt of country for miles north and south of Lincoln, as shown in the map (Fig. 194), is almost without villages, a long line of which is situated on each side of it, on the outcrop of the Lias to the west, and the Great Oolite to the east.

The following diagram[2] (Fig. 195) indicates the reason. The open porous limestone supplies no water, but along each side is a line of springs which has determined the position of the villages.

[1] Lapworth, *Proc. Geol. Ass.* vol. xv. 1897-98.
[2] Ussher, *Mem. Geol. Surv.*, Lincoln.

In Oxfordshire also the junction of the Lower

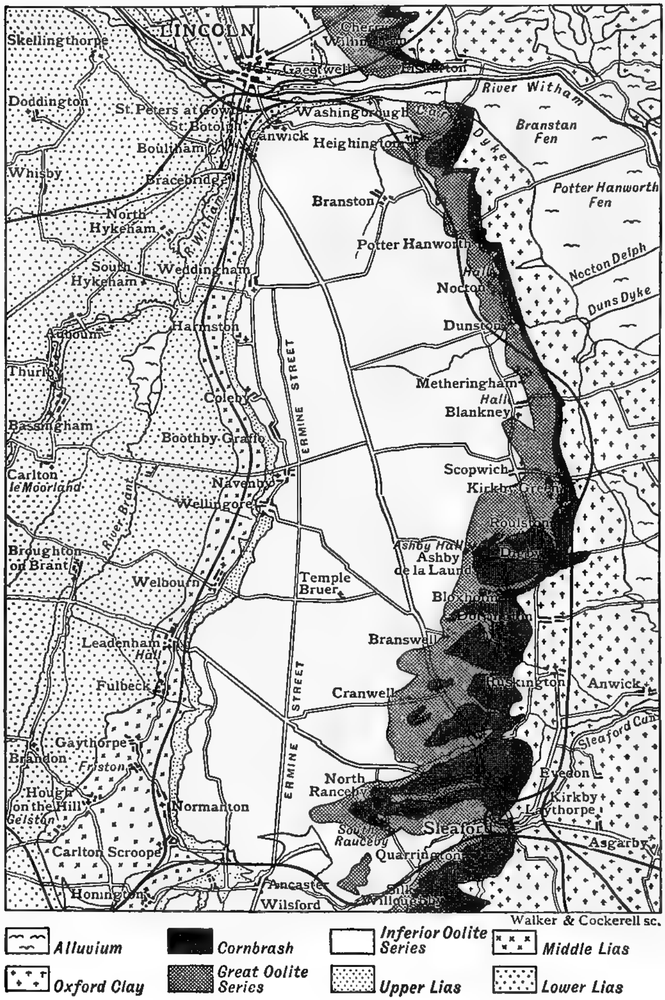


Fig. 194.—Map from Lincoln to Sleaford.

Chalk with the Greensand is well marked by springs, which in the same way have given rise to a line of villages.

In the South-west of England the outcrop of the Cornbrash is marked by a line of villages which are due, "not only to the fertility of the Cornbrash, but to the circumstance that this porous rock, resting on the impervious Forest Marble, is a collecting ground for water, which is kept up by the latter formation."[1]

Topley has also pointed out that in Eastern Northumberland, which is much covered by Boulder-clay, through which rise isolated patches of rock belonging to the older formations, these have generally been selected for the sites of villages and country

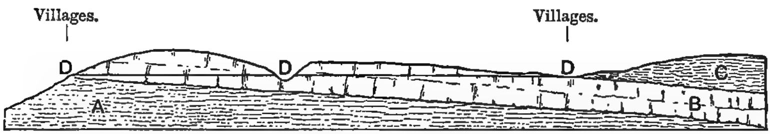


Fig. 195.—Illustration of position of Lincolnshire Villages. A, Lias; B, Lincolnshire Limestone; C, Great Oolite; DDD, line of saturation with springs at points of intersection with surface.

houses. So also in Cheshire, the city of Chester, and many of the villages round—for instance, Aldford, Eccleston, Saighton, Christleton, Waverton, Thornton, Hapsford, Dunham, Barrow, Tarvin, and Tattenhall—are all on knolls of Sandstone which rise above the Boulder-clay.

In other districts, where the Boulder-clay in parts presents patches of gravel left by ancient rivers, the villages are generally situated on these gravel areas.[2]

The site of the city of York was perhaps determined by the great moraines which rise over the Boulder-clay.

[1] Woodward, *Geology of England and Wales.*

[2] See, for instance, Jukes-Browne, *Mem. Geol. Surv.*, South-west Part of Lincolnshire.

The London Clay also had a deterrent effect. It is, however, covered in many places by sand and gravelly deposits, which were soon built over, being dry and wholesome, while they were well supplied with water, which was held up by the impervious clay beneath. The districts, on the other hand, where London Clay came to the surface were left almost unoccupied until the New River and other Water Companies did away with the necessity for wells. The large area of bare London Clay round Harrow is still comparatively free from houses.

A glance at the map will show that our towns and cities, though they often stand near, are seldom actually at the mouths of, the rivers. London, Bristol, Liverpool, Newcastle, and many smaller places might be mentioned. In some cases this may be due to the fact that the navigation up the river, which offered no serious difficulty to the natives was a great protection against Vikings and pirates.

The position of London, however, is perhaps due to another cause. Farther down the river we have now a tract of broad marshes, below high-water level, but protected by banks, which are no less than 50 feet above low-water line, and, counting those which run up the side creeks, some 300 miles long; truly a gigantic work. Before these banks were thrown up, the whole of the Greenwich, Woolwich, and Plumstead marshes were flooded at high-water, while at low-tide they were treacherous mud-flats, cut through by winding creeks and quite unsuitable for human dwelling.

London was built on the first spot going up the river where any considerable tract of dry land touches the stream. It is a tract of good gravel, well supplied with water, not liable to flooding, and not commanded by neighbouring higher ground. It was therefore admirably suited for the first human settlements, and the wisdom of the choice has been ratified by the continuous growth of the great city.

CHAPTER XVII

CONCLUSION

Having thus described very briefly some of the main features of English scenery in some detail, it may perhaps be permissible to end with some general considerations.

The theory of the origin of the Planetary System known as the "Nebular Hypothesis," which was first suggested by Kant and developed by Herschel and Laplace, has attained a degree of probability practically amounting to proof. The space now occupied by the solar system is supposed to have been filled by a rotating spheroid of extreme tenuity and enormous heat, due perhaps to the collision of two originally separate bodies. The heat, however, having by degrees radiated into space, the gas cooled and contracted towards a centre, destined to become the sun. Through the action of centrifugal force the gaseous matter also flattened itself at the two poles, taking somewhat the form of a disc. For a certain time the tendency to contract and the centrifugal force counterbalanced one another; but at length a time came when the latter prevailed, and the outer zone

detached itself from the rest of the sphere. One after another similar rings were thrown off, and then, breaking up, formed the planets and their satellites.

That each planet and satellite did form originally a ring we still have evidence in the wonderful and beautiful rings of Saturn, which, however, in all probability, will eventually form spheroidal satellites like the rest. Thus, then, our earth was orginally a part of the sun, to which again it is destined one day to return. Plateau has shown experimentally that by rotating a globe of oil in a mixture of water and spirit having the same density, this process may be actually repeated in miniature.

This brilliant and yet simple hypothesis is consistent with, and explains many other circumstances connected with, the position, magnitude, and movements of the planets and their satellites.

The planets, for instance, lie more or less in the same plane, they revolve round the sun and rotate on their own axes in the same direction—a series of some thirty coincidences which cannot be accidental, against which the odds would be many millions, and for which the theory would account. Again, the rate of cooling would of course follow the size: a small body cools more rapidly than a large one. The moon is cold and rigid; the earth is solid at the surface, but intensely hot within; Jupiter and Saturn, which are immensely larger, still retain much of their original heat, and have a much lower density than the earth; and astronomers tell us on other grounds that the sun itself is still contracting, and

that to this the maintenance of his temperature is due.

Although, therefore, the Nebular Theory may not perhaps have been absolutely proved, it has certainly been brought to a higher state of probability than many theories which are regarded as certain, and is, in its main features, generally accepted by astronomers.

Indeed, it is a question whether the other stellar groups may not have been similarly evolved, and form with ours one great system.

The rotation of the earth gives it the shape of an orange, or in scientific language an oblate spheroid, flattened at the poles. But it is also affected by the shrinking due to gradual loss of temperature. When the globe had cooled down sufficiently, a solid crust would form at the surface. This would gradually thicken, and there has been much difference of opinion as to the degree to which this has progressed. Many have supposed that even now the solid crust is comparatively thin, having regard to the size of the globe. The average density of the whole earth, however, is about 5½ times that of water, so that the interior must be very dense. From this and other considerations Lord Kelvin and others have inferred that the whole earth is solid, and as elastic as steel. The changes which have taken and are taking place in level, and other considerations, seem to me to throw some doubt on this view. I am, however, prepared to accept Professor G. Darwin's calculation that the prominent inequalities of the earth's surface could not be sustained unless the crust be as rigid as granite

for a depth of 1000 miles. If, he says, "the earth be solid throughout, then at 1000 miles from the surface the material must be as strong as granite. If it be fluid or gaseous inside, and the crust 1000 miles thick, that crust must be stronger than granite, and if only 200 or 300 miles in thickness, much stronger than granite."

However this may be, the gradual cooling of the earth would inevitably throw the crust into great folds. The general form which would give the largest amount of surface for the smallest volume would be a six-faced tetrahedron. Lowthian Green, in a most suggestive work,[1] has thrown out this suggestion, and worked it out in some detail. He observes that a spherical shell may be theoretically regarded as consisting of an infinite number of circular rings, and refers to certain experiments made by Fairbairn[2] on the manner in which short tubes act under pressure. Fairbairn shows that they collapse from three equidistant points, thus assuming a three-cornered or three-lobed section (Fig. 196).

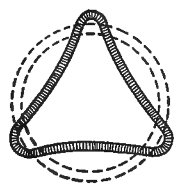


Fig. 196.

If, then, we imagine the earth as a solid tetrahedron and the ocean as a sphere, somewhat flattened at the poles, we should have three continental projections running from near one pole towards the other, at which the fourth prominence would form another great continent. He gives a figure exhibiting "the relation

[1] *Vestiges of the Molten Globe.*

[2] Fairbairn's *Useful Information for Engineers*, 2nd Ser., 1860.

between sections of a collapsed wrought-iron tube, of a solid angle of a six-faced tetrahedron at right angles to an axis, and of the earth at the Tropic of Capricorn, or indeed through almost any parallel of latitude, showing in each case a collapse from three equidistant directions towards the centre."[1]

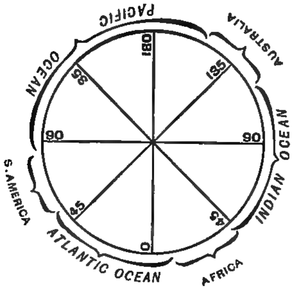


Fig. 197.

The distribution of land and water on the earth's surface looks at first sight so irregular, that it might well seem impossible to explain even the main features on any general principles.

Nevertheless, we may say that there are three main oceans—the Atlantic, the Pacific, and the Indian, to which perhaps the Arctic should be added as a fourth; and three main continents, those of Europe-Africa, North and South America, and Asia-Australia, to which perhaps the Antarctic should be added as a fourth.

Europe and Asia form a single mass of land, but it is not without good reason that they have always been considered as two continents. A depression extends along the east of the Urals, and a very slight alteration of level would submerge the land from the Black Sea by the Caspian—the surface of which is about 100 feet below that of the Black Sea—to the Arctic Ocean. If the above theory be correct, the great oceans must date back to the very commencement of the solidification of the earth's crust, though of

[1] Green's *Vestiges of the Molten Globe.*

course the actual boundaries have undergone great and frequent alterations. Green's interesting hypothesis throws light, moreover, upon some other main features of the earth's surface. The three great continents are all torn across, as it were—America by the Gulf of Mexico, Europe-Africa by the Mediterranean, Asia-Australia by the Straits of Sunda; and they all tend eastwards in their southern parts. South America is almost entirely to the east of North America, and the same tendency is shown by South Africa and Australia.

Now, in a rotating sphere the different parts would have concordant velocities. But as soon as the protuberances corresponding to the continents commenced to develop, the northern protuberances would have a diminished and insufficient velocity, having regard to their new and increased distance from the centre. The southern lands, on the contrary, would have an excess of velocity. There would therefore be a tendency to torsion, giving rise to a line of rupture between the north and south, and carrying the southern lands somewhat to the east. This consideration may account for the remarkable depression which runs round the world, forming the Gulf of Mexico, the Mediterranean, the Persian Gulf, and the sea between Asia and Australia.

These suggestions cannot yet be said to have received the general assent of geographers, but they are very interesting, and seem to throw light on some of the fundamental features of the geography of the earth.

De Lapparent has also shown[1] (though the subject is too intricate to be discussed here) that this would explain the excess of weight which the pendulum indicates over the great oceans.

It follows also that the earth was once considerably larger than it is at present, that the mountains are portions which have retained their elevation, rather than districts which have undergone elevation. Folded chains, such as the Alps, are no doubt compressed sea-beds, but these are after all subsidiary; and as regards continents and oceans, it is the ocean-beds which have sunk rather than the continents which have risen.[2]

Michel Lévy has recently applied Green's suggestions to the study of igneous rocks. These have issued from the interior along lines of fracture, and a study of their directions has led him to the conclusion, not indeed that the earth tends to the figure of a tetrahedron, but that it fractures on lines following the ridges of a tetrahedron. Following up the same idea, Bertrand points out[3] that all the recent eruptions have taken place along six slightly sinuous belts, which however widen, or double themselves here and there, enclosing certain great areas of depression or

[1] De Lapparent, *Traité de Géologie.*

[2] According to Davison the earth consists of: (1) A central mass comprising $\frac{9}{10}$ of the volume, and in which the temperature has practically not varied. (2) An envelope, which he estimates to be about 400 miles, which is cooling and contracting, and which therefore is stretched or rent so as to rest on the uncontracted mass within. (3) A layer of no tension of about 5 miles in thickness. (4) A thin layer which has cooled down, and, being subjected therefore to tangential compression, must either break or bend.—*Phil. Trans.* vol. clxxviii. 1887.

[3] Bertrand, *Comptes Rendus*, vol. cxxx. 1900.

volcanic activity, as if the tetrahedral points were truncated.

The great oceans differ much in character. The Atlantic, to judge merely from the present outlines of land and water, might be supposed to extend to Spitzbergen or even farther. There is, however, a submarine plateau at a depth of about 400 to 500 metres which extends from Greenland by Iceland to the British Isles, and which separates the ocean depths of the Atlantic on the south from those of the Arctic Ocean on the north.

The Atlantic has a comparatively uniform coast-line. It presents a central ridge with a deep depression on each side, and on the north a plateau slightly below the water-line, on which stand certain groups of islands, but in the central and south Atlantic (excluding the Gulf of Mexico) the only islands are a few volcanic cones. It is also remarkable for the absence of mountain chains parallel to the coast. Even when a chain approaches the ocean, as do the Appalachian Mountains, it turns its back to the coast. The highlands of Brazil are lofty plains and not mountain chains. The ocean appears to be quite independent of the mountains. The greatest depths are near the Virgin Islands, where the bottom descends to 8300 metres.

The Atlantic receives far more than its proportion of rivers. Penck estimates that of the whole land surface 27 per cent drain into the Pacific and Indian Oceans, 22 per cent have no outlet to the sea, and no less than 51 per cent are tributary to the Atlantic.

This large proportion is greatly due to the lofty chain of the Andes and the Rocky Mountains, which drive almost the whole rainfall of South and a great part of North America to the east.

The Pacific affords a great contrast. It is enclosed by folded mountain ranges, which turn their outer edge to the ocean, follow the coasts, and do not, as is the case round the Atlantic, run at right angles to them. The Atlantic mountains run east and west, the Pacific north and south. The two sides of the Pacific, again, offer a great contrast. The eastern part is bounded by a great range of lofty mountains, the ground sinks abruptly to great depths, and there are very few islands. The islands in the centre form numerous groups, rising from great depths, while as they approach the mainland they tend to arrange themselves in great garlands or curves—the Aleutian Islands, Japan and the Kuriles, the Philippines, always presenting their *concave* sides towards the continent, from which they are separated by water of immense depth. These islands evidently represent the summits of ridges, and the tracts between them and the mainland are areas of subsidence. Behring Sea reaches a depth of 4000 metres.

The submarine slopes are often extremely steep. The Bermudas stand on a mountain summit, with seldom more than 15 to 20 metres of water, but with sides so abrupt that at 15 kilometres from the edge the depth all round reaches from 2200 to 2500 metres.[1]

[1] De Lapparent, *Leç. de Géog. Phys.*

Africa, south of the Sahara, may be described as a great and ancient plateau, riven in places by immense fractures, such as that which has given rise to the great lakes and which is continued up the Red Sea, the Gulf of Akaba, the valley of the Dead Sea (which descends 1300 feet below the sea-level), and of the Jordan. The Atlas may be said to be the only true African mountain chain. In Southern Africa the plateau has slightly sunk in the centre. The range of the Drakenberg slopes up gently towards the south-east and then drops suddenly; offering thus a succession of steep slopes, of which the Boers knew so well how to avail themselves during the South African war. They had a gentle ascent up which to draw their guns and supplies, and we had to attack up very precipitous, in most places almost perpendicular, cliffs.

"Table Mountain" at the Cape well expresses this character of the land. Of all parts of the earth South Africa is that in which the line of 1000 metres approaches nearest to the sea-coast, while below the sea-level the bottom sinks abruptly to abyssal depths.

It used to be supposed that the Arctic Ocean was comparatively shallow. Recent researches, however, and especially those of Nansen, have shown that it attains great depths, and it is now generally regarded as a comparatively depressed area, while the Antarctic region, on the contrary, forms a protuberance.

The ocean occupies three-fourths of the earth's

surface, but this comparison does not give a correct idea of the volume of water; for while the average height of the continents is only about 1000 feet,[1] the average depth of the oceans is estimated at 13,000, and if the water was spread evenly over the surface the depth would be over 8000 feet.

The deposits in the ocean depths are, moreover, exclusively organic, volcanic, or meteoric; they comprise no materials brought from the shore.

These facts, therefore, point to the conclusion that while parts of the world have been sea and then land, land and then sea, many times over, others have remained permanently either ocean or continent.

Chambers long ago[2] called attention to the number and horizontality of the marine terraces round our coast. If the land had been elevated we should have expected that these terraces would slope in various directions. If, on the contrary, owing to the gradual subsidence of the ocean depths, the water has been drained away from the land, the terraces would retain their original horizontality.

Professor G. Darwin[3] has attempted to show from astronomical considerations that the primitive wrinkles would trend about north-east by south-west in our latitude.

Moreover, if the great wrinkles and fractures of the earth are due to gradual contraction, it seems evident, as already pointed out (ante, p. 184), that

[1] Carpenter estimated it at 1000 feet, Krümmel makes it 440 metres.

[2] *Ancient Sea Margins.*

[3] "On Problems connected with the Tides of a Viscous Spheroid," *Phil. Trans.* vol. clxx. 1879.

there must always be two series, one at right angles to the other.

Dr. Gregory, in a very interesting paper on "The Plan of the Earth and its Causes,"[1] objects to my suggestion because, he says, "What is doubtful is whether any extensive trace of their influence can be discerned in the present distribution of land and water. A map of the world in early Cambrian times might show the influence of these pre-geological incidents, but their geographical effects seem to have been obliterated by the changes of geological times."

I will not here discuss the torsion lines due to the moon's action, which have been suggested by Professor G. Darwin in the memoir already referred to, and which he considers would raise wrinkles on the surface running in a direction perpendicular to the axis of greatest pressure, *i.e.* along a line running north and south at the equator, with a trend in the north to the north-east, and the south to the south-west.

As regards Dr. Gregory's suggestion, however, that the geographical effects of "pre-geological" or early geological incidents would be "obliterated by the changes of geological times," I may remark that folds once started would establish lines of weakness, and thus tend, as Bertrand has shown,[2] to repeat themselves again and again, though not, of course, to the exclusion of others.

It is probable, then, that as soon as the contraction

[1] *Geog. Journ.* vol. xiii. 1899.
[2] *Bull. Soc. Géol. France,* t. xx. 1892.

due to the cooling of the earth began to throw the surface into wrinkles, these would take a north-eastern or south-western direction. How prevalent such lines are, a glance at the map will show. I need only mention the west coast of Europe and North Africa from North Cape to Cape Blanco, the eastern coast of Asia from Kamskatka to Siam, and the eastern coast of North America from Greenland to Florida. But, if my argument is well founded, ridges in any direction due to such a cause would be accompanied by others approximately at right angles to them. Such are the west coast of North America from north of British Columbia to Panama, the coast of Labrador, the western coast of Greenland, the western coast of the British Isles, the Red Sea, etc. There are no other lines of direction comparable with these in importance.

We cannot expect these lines to be straight or the directions to be mathematically true. Various circumstances would give rise to considerable deviations. Moreover, as the evidence shows, the lines have a tendency to bifurcate and reunite.

Nature has provided for us an admirable illustration in the case of the Jura. It will be seen there that the folds do not take the form of absolutely straight and parallel lines, but of elongated ellipses or lenses often bifurcating and then reuniting. The main folds run south-west and north-east, with cross-lines, as for instance the depression from Pontarlier by Jougne to Vallorbe; that by Delle, Porrentruy, St. Ursanne, and Biel; that by Basle,

Liestal, and Olten, etc., all of which have been adopted by rivers and railway companies.

They follow the direction indicated by Professor G. Darwin, namely from south-west to north-east.

I have already (see ante, p. 101) shown the predominance of this line, and one at right angles to it, on the configuration of our country.

I submit, then, that so far from its being doubtful whether any extensive trace of these double folds can be discerned in the present distribution of land and water, the effect is still clearly shown on the earth's surface, and that in the British Islands we have a most instructive illustration.

These two lines—namely, from south-west to north-east, and at right angles from north-west to south-east—seem to me the two great guiding lines which have determined the general features of the geography of our earth.

Another remarkable feature is the tendency of so many great masses of land to point southwards—South America, Africa, India, etc.

Many of the peninsulas, moreover, have an island, or group of islands, at their extremity, as South America, which is terminated by the group of Tierra del Fuego; India has Ceylon; Malacca has Sumatra and Borneo; the southern extremity of Australia ends in Tasmania or Van Diemen's Land; a chain of islands runs from the end of the peninsula of Alaska; Greenland has a group of islands at its extremity; and Sicily lies close to the southern termination of Italy.

Some years ago I ventured to suggest[1] that we might correlate this with the remarkable preponderance of ocean in the southern hemisphere, which Adhémar has suggested to be due to the alteration of the centre of gravity of the earth, caused by the great southern cupola of ice.

However that may be, the preponderance of water in the south is very remarkable. Taking each parallel as unity, the proportion of sea is as follows:—

60° North	0,392	10° South	0,795
50 „	0,438	20 „	0,763
40 „	0,538	30 „	0,797
30 „	0,567	40 „	0,961
20 „	0,574	50 „	0,983
10 „	0,758	60 „	1,000
0 „	0,783		

Without at the present moment entering upon any discussion as to the cause which has produced this remarkable result, the fact at any rate seems to throw some light on the southern direction of promontories. For let us suppose three tracts of land, each trending north and south, each with a central backbone, but one with a general slope southwards, one with a northward slope, and the third without any. The first will, of course, form a peninsula pointing southwards, because, as we proceed southwards, less and less of the surface will project above the water, until nothing but the central ridge remains. The other two, however, would also

[1] *Nature*, vol. xv. 1877. See also a paper in the *Geogr. Jour.* vol. vi. 1895.

assume the same form, because, though by the hypothesis the land does not sink, still, the gradual preponderance of water would produce the same effect.

If, moreover, the central mountain ridge, as is so generally the case, presents a series of detached summits, the last of such elevations which rises above the water-level will necessarily form an island. This suggests a possible reason for the position of Ceylon, Tierra del Fuego, etc. Africa, however, unlike the other south-pointing lands, has no island at its extremity. The Cape of Good Hope, on the contrary, is not a folded range but a table mountain, bounded by two converging areas of subsidence, which meet at Cape Town. In such a case no island would be present.

So far as I am aware, no notice has been taken of this suggestion except by Penck, who characterises it as self-evident. However this may be, it had not been previously pointed out; and indeed an objection, to which for long I saw no answer, was suggested to me by Francis Galton. He urged that no accumulation of water in the northern hemisphere would give promontories pointing to the north. This is true, but the explanation lies, I think, in the necessary equivalence of the great folds on the earth's surface.

If folded mountains are due, as above suggested, to a diminution of the diameter of the earth, every great circle must have participated equally in the contraction. The east and west folds would on the

whole counterbalance those from north to south. This must be so theoretically, but we have no means of testing it by exact figures. It is interesting, however, to observe that while the principal mountain chains of the Old World run approximately from east to west, those of America are in the main north and south. Speaking roughly, the one series would seem to balance the other, and we thus get a clue to the remarkable contrast presented by the two hemispheres. Again, in the northern hemisphere we have chains of mountains running east and west —the Pyrenees, Alps, Carpathians, Himalayas, etc., while in the southern hemisphere the great chains run north to south—the Andes, the African ridge, and the grand boss which forms Australia and Tasmania.

This, then, seems to me the answer to the difficulty suggested by Galton. The principal mountain chains in the southern hemisphere running north and south give us when combined with the preponderance of water the southern-pointing promontories. No such preponderance, however, in the northern hemisphere would give us northern pointing promontories, because there the great folds run not from north to south, but from east to west.

Thus, then, the explanation of great mountain ridges by lateral pressure and consequent folding, coupled with the necessity of approximately equivalent contraction along every great circle, explains the balance of east and west and north to south chains in each hemisphere; and this again, in conjunction with

the preponderance of water in the south, explains the tendency of land masses to taper southwards and end with an island or group of islands, thus throwing an interesting light on some of the principal features in the configuration of the earth's surface.

Appendix

LIST OF WORKS REFERRED TO

Memoirs of the Geological Survey of the United Kingdom referring to the following towns and districts.

Berwick-on-Tweed, Coast South of. By W. Gunn.
Brent Tor and Neighbourhood, Eruptive Rocks. By F. Rutley.
Bridlington Bay. By J. R. Dakyns and C. Fox-Strangways.
Cambridge. By W. H. Penning and A. J. Jukes-Browne.
Cambridge and Suffolk. By W. Whitaker, H. B. Woodward, F. J. Bennett, S. B. J. Skertchly, and A. J. Jukes-Browne.
Carlisle. By T. V. Holmes.
Cheltenham. By E. Hull.
Cheviot Hills (English side). By C. T. Clough.
Cromer. By C. Reid, with Notes by H. B. Woodward.
Derbyshire, North. By A. H. Green, C. Le Neve Foster, and J. R. Dakyns, with additions by A. Strahan.
Fenland. By S. B. J. Skertchly.
Flint, Mold, and Ruthin. By A. Strahan (with parts by C. E. de Rance).
Holderness and adjoining parts of Yorkshire and Lincolnshire. By C. Reid.
Ipswich, Hadleigh, and Felixstow. By W. Whitaker, with Notes by W. H. Dalton and F. J. Bennett.
Isle of Wight. By H. W. Bristow, C. Reid, and A. Strahan.
Lake District, North Part. By J. C. Ward.
Lincoln. By A. J. Jukes-Browne and A. Strahan, with Notes by W. H. Penning, W. H. Dalton, and A. C. G. Cameron.
Malvern Hills. By J. Phillips (vol. ii. of the General Memoirs).
Midland Counties, Triassic and Permian Rocks. By E. Hull.
Norfolk, South-Western, and Northern Cambridgeshire. By W. Whitaker, S. B. J. Skertchly, and A. J. Jukes-Browne.

Northumberland, including the country between Wooler and Coldstream. By W. Gunn and C. T. Clough, with Petrological Notes by W. W. Watts.
Norwich. By H. B. Woodward, with Notes by J. H. Blake and C. Reid.
Otterburn and Elsdon. By H. Miller, with Notes by C. T. Clough.
Purbeck, Isle of, and Weymouth. By A. Strahan.
Rutland and parts of Lincoln, Leicester, Northampton, Huntingdon, and Cambridge. By J. W. Judd.
Somerset, East, and Bristol Coal Fields. By H. B. Woodward, with Notes by H. W. Bristow, W. A. E. Ussher, J. H. Blake, and F. Rutley.
Stockport, Macclesfield, Congleton, and Leek. By E. Hull and A. H. Green.
Wales, North. By A. C. Ramsay (vol. iii. of the General Memoirs).
Wales, South, and South-western England. By H. T. De La Beche (vol. i. of the General Memoirs).
Weald, parts of Kent, Sussex, Surrey, and Hants. By W. Topley.
Wiltshire and Gloucestershire. By A. C. Ramsay, W. T. Aveline, and E. Hull.
Yarmouth and Lowestoft. By J. H. Blake.
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